

Status Report #2

Diamond Head Bench-Scale Test Summary

PREPARED FOR: USEPA and USACE

PREPARED BY: CH2M HILL

DATE: March 31, 2011

1. Introduction

This technical memorandum (TM) presents the results-to-date of laboratory bench-scale testing of light non-aqueous phase liquid (LNAPL) solubility, soil solidification/stabilization (S/S), and the application of biocell technology to the treatment of contaminated soil from the Diamond Head Superfund site in Kearny, New Jersey. This testing was conducted at CH2M HILL's Applied Sciences Laboratory (ASL) in Corvallis, Oregon as described in *Treatability Study Test Plan for the Diamondhead Superfund Site* (CH2M HILL, August 26, 2010). This report is the second in a series of reports prepared to update the project team of testing results and provide support for decision making on the applicability of the biocell technology. This report summarizes some of the information presented in the first report entitled *Status Report #1, Diamond Head Phase 1 Biocell Test Startup* (CH2M HILL, December 2010), but additional details (i.e., photos) may be found in the original report.

2. Background

The Phase 1 Remedial Investigation (RI) determined that LNAPL-containing soil was pervasive throughout the site (CH2M HILL, February 2005). A Focused Phase 2 RI was performed (CH2M HILL, February 2009) and applied multiple investigative techniques to define the extent and nature of the LNAPL including in-well LNAPL thickness monitoring, laser-induced fluorescence (LIF), field screening and analysis of LNAPL in soil borings, intact coring and petrophysical analysis, LNAPL mobility and recoverability analysis, and synthetic precipitate leaching procedure (SPLP) testing. The results of the Focused Phase 2 RI showed that LNAPL mobility is extremely limited and that the LNAPL is not practically recoverable using fluid recovery means. However, the limited SPLP data and the groundwater sampling results suggested that LNAPL was leaching contaminants to groundwater.

The Focused Phase 2 RI also included performing an air/biosparging pilot test to evaluate the ability to enhance aerobic biodegradation of contaminants in groundwater. The pilot test results indicated that the air/biosparge test created and maintained aerobic conditions in the shallow saturated zone. Biological indicators suggested increases in biomass, changes in the community structure to more aerobic bacteria, and creation of a generally more favorable environment for bacteria present in the subsurface. Based on these results, some additional bench testing was recommended to determine the effect of the pH on biological activity and its ability to reduce the leachability of LNAPL.



Following a Focused Feasibility Study (FFS, CH2M HILL, June 2009), ex-situ enhanced bioremediation through aerobic biocell treatment technology was selected in the Record of Decision (ROD) for the Operable Unit 1 (OU1) LNAPL Source Area (September 2009). The primary remediation goal (RG) specified in the ROD was to remediate the most highly contaminated material that, without early attention, would result in ongoing contamination of currently uncontaminated areas. The following specific goals were also established for the remedy:

- Areas where measurable thickness of LNAPL was found in monitoring wells will be treated to no measurable thickness in-well
- Areas where the potential for LNAPL-contaminated soil to leach oil and grease to groundwater as measured by the SPLP or comparable test will be treated to non-detect (i.e., sheen measurement of "none-noticeable" per New Jersey Department of Environmental Protection [NJDEP]) levels.

To assess whether the selected technology would work in the actual conditions found at the Diamond Head site, bench tests were recommended in both the ROD and FFS. These tests were planned to fill the data gaps identified in the RI and FFS, assess the applicability of the technology to site conditions and its ability to meet the RGs, and if found applicable, provide additional data to support the design of an aerobic biocell.

3. Bench Test Objectives

The objectives established for this bench test include the following:

LNAPL Solubility Testing - The first objective is to determine the water solubility of LNAPL from various locations across the site, measured as a concentration of hexane extractable material, or oil and grease (O&G), as defined by EPA Method 1664. The second objective is to determine the effective solubility of selected volatile organic compounds (VOCs) in water that are in direct contact with LNAPL, as defined by EPA Method 8260.

Soil Solidification/Stabilization (S/S) Testing - The objective is to determine the amount of Portland cement that must be blended with a given quantity of soil to absorb the free liquids and allow the sample to pass the paint filter test.

Biocell Treatment Testing - The overall goal of this testing is to evaluate soil contaminant treatability and develop design and operating data for an aerobic biocell. Specific objectives are to:

- Assess the applicability of the technology and its treatment effectiveness for the monitored contaminants
- Determine the "best" combination of amendments (pH adjustment, bulking agent, nutrients, and bioenhancement)
- Determine oxygen uptake rates
- Evaluate leachate quality
- Evaluate gaseous emissions

4. Sample Collection

Sample collection activities were conducted from September 27 through October 1, 2010. Samples were shipped on ice by overnight courier, where upon receipt at ASL, the samples were stored at 4 °C until testing began. Three large composite soil samples were collected from multiple test pits dug throughout the study area to represent three different degrees (i.e., High, Medium, Low) of LNAPL contamination in soil at the site. Because of the heterogeneous nature of the materials and occurrence of concrete slabs, 29 test pits were completed versus the 14 that were planned to target areas of different LNAPL occurrence in soils. Additional pits were required to visually observe the differing nature of the soils and gather soils that were of the characteristics needed for each component of the bench-scale testing. Visual evidence of High-, Medium-, and Low-degree of LNAPL contamination was used to assign soil samples from each test pit to its respective bench test composite sample. In addition to the three samples of High-, Medium-, and Low-soils, samples were also collected for solidification/stabilization testing. Table 1 (attached at the end of the TM) presents a summary of the observations from test pits that were dug and which composite sample they were used for.

The large surface area of the test pits provided new insight into site conditions with several observations differing from the information collected previously from soil borings using drill rigs. A brief list of observations relevant to the bench testing and overall for the biocell remedy is provided below.

- The 'clay' unit in some areas of the historic oil lake appeared to possibly have been reworked and/or significantly affected by LNAPL. Areas of clay-like petro-sludge were observed.
- Concrete slabs were found at many locations at about 6 ft bgs. These may be indicative of the presence of concrete lined basins associated with the 'subsurface pits' noted in historic documents. LNAPL appeared to occur below some of these concrete slabs as they were located adjacent to piezometers with measureable LNAPL thicknesses.
- Perched lenses of LNAPL were observed seeping into the test pits above the observed water table. The water table was observed deeper than anticipated (6-9 ft bgs). Note that it had been a historically dry summer.
- Areas with relatively low visual LNAPL impacts were observed in the northern half of the site (closer to the former process building) but high photo-ionization detector (PID) readings (> 100 parts per million [ppm]) were encountered and a 'chemical / solvent' type odor was noted. No visual evidence of staining was observed on the soils.
- Unanticipated soil conditions were observed including a clean white clay-like material and a mottled yellow and purple-red material with high PID readings.

LNAPL samples were collected from one monitoring well (MW-13) and two piezometers (PZ-10, PZ-14) for LNAPL solubility analysis. Groundwater samples from below the LNAPL were also collected using special LNAPL-bias eliminating techniques.

The locations of the test pits, monitoring wells, and piezometers that were sampled are shown on Figure 1 (attached at the end of the TM). More details of the field effort can be found in the OU1 LNAPL Source Area Bench Scale Sample Collection Field Documentation (CH2M HILL, October 18, 2010).

5. LNAPL Solubility Testing

LNAPL solubility testing was performed to determine the effective solubility of VOCs and O&G in three LNAPL samples from the site. Solubility was evaluated at three mixing periods, two temperatures spanning the range of groundwater temperatures expected at the site, and two pH values. The objectives were to evaluate the effects of these variables on solubility. Groundwater samples collected from beneath the LNAPL layer using special LNAPL-bias eliminating techniques were also analyzed for VOC and O&G concentrations to evaluate the effective solubility that may be realized in the field.

5.1 Test Setup and Monitoring

The test procedure is summarized below.

1. For each of the first two sample locations (MW-13S and PZ-10), six 1 L glass bottles with Teflon-lined septa screw caps were set up with approximately 960 mL of Milli-Q water, 40 mL of LNAPL, and a large stir bar. The bottles were securely capped and all setup quantities and start times were recorded.
2. Six test vessels were placed on magnetic stirrers on a multi-position stir unit at room temperature in the lab (21 °C), while another six vessels were placed on a similar unit in an incubator set for the target temperature of 15 °C. These vessels were mixed continuously until sacrificed for analysis
3. At the specified monitoring times, one vessel of each sample from each temperature was removed, the bottles were turned caps-down, and the water and organic phases were allowed a minimum of 48 hours to separate. After the phases had visually separated, for each sample, two syringe needles were inserted through the cap septa. The first was a long needle designed to reach to the top of the bottle interior to provide ventilation. The second was a shorter needle designed to allow drainage of the aqueous phase. The drainage needle was connected to tubing with a valve. Sample aliquots of the aqueous phase sample were transferred to appropriate containers for analysis.
4. Aqueous sample aliquots were submitted to the lab for analysis of Oil and Grease (O&G), O&G with Silica Gel Cleanup (SGT), and VOCs.
5. Steps 3 and 4 were repeated for each specified monitoring time.
6. The test was repeated for the samples from the remaining sample location (PZ-14). The pH-adjusted test was also performed on samples from PZ-14. However, for the pH-adjusted test only 3 test vessels were set up, the pH of the solution in each of these vessels was adjusted to pH 4.5 with dilute hydrochloric acid (HCl) during test setup, and the test was performed only at room temperature.

5.2 Results

The concentrations of VOCs and O&G with time for each solubility test sample are shown in Table 2 (attached at end of the TM). Parameters that exceeded the NJDEP Class IIA groundwater quality criteria were visible O&G, benzene, tetrachloroethene (PCE), and trichloroethene (TCE), cis-1,2-dichloroethene (DCE), and vinyl chloride (VC). The same parameters were noted to exceed the criteria in the analyzed groundwater samples.

The remainder of the discussion below focuses solely on those chemicals of concern that exceeded NJDEP Class IIA criteria in either the groundwater or LNAPL solubility samples.

The locations sampled are in an approximate north-northeasterly groundwater flow line from the most upgradient PZ-10, to PZ-14, and finally to the most downgradient MW-13S with approximately 100- to 150-feet in between them (2.5 to 250 ft/yr groundwater seepage velocity). While benzene exceeded criteria in all solubility and groundwater samples, PCE and TCE exceeded in PZ-14 solubility samples and cis-1,2-DCE and VC exceeded in PZ-10. No chlorinated VOCs exceeded criteria in MW-13S. On average, benzene (20-70 µg/L) and O&G with silica gel treatment (SGT) (71-181 mg/L) concentrations were similar, but highest in PZ-10 and lowest in MW-13S. There does not appear to be a correlation of well location with the occurrence of chlorinated VOCs.

SGT removed a significant fraction of plant and animal oils and fats from the total O&G by EPA Method 1664; the petroleum-contaminant-related fraction of O&G ranged from 34 to 77 percent of the total O&G. This indicates that SGT is a necessary component of the O&G analytical procedure to ensure that natural materials are removed. The remainder of this analysis focuses on O&G w/ SGT results.

Visible O&G (i.e., a sheen) was observed in all groundwater samples, but not all solubility samples. The LNAPL solubility results from PZ-10 show no visible sheen with O&G with SGT concentration as high as 545 mg/L and no sheen in the LNAPL solubility sample from PZ-14 with 859 mg/L of O&G with SGT. On the contrary, the results from MW-13S show visible sheen on O&G of 19.9 mg/L in groundwater and O&G with SGT samples with concentrations of 20.5 and 21.0 mg/L in the LNAPL solubility samples. No visible sheen was noted in LNAPL solubility samples with O&G with SGT concentrations less than or equal to 18.5 mg/L (two samples). As such, a conservative threshold of 8 mg/L of O&G with SGT (42 percent of 19.9 mg/L O&G in MW-13S groundwater) may be used as the lower limit above which visible sheen may be present. The 42 percent factor was derived from the maximum reduction O&G occurring as a result of SGT for samples where a sheen was observed (PZ-14 at 66 hours and 15 °C).

There was generally no significant difference in VOC concentrations observed between the three different mixing times. The 18 hour VOC concentration was generally within 20 percent of the results from the 42, and 66 hour samples.

Slightly higher VOC concentrations were observed in the samples run at 21 °C. VC was detected only at the higher temperature. The time step-averaged benzene in the sample from PZ-14 (73 µg/L) was higher by 1.5 times than the time step-averaged lower temperature concentration. Temperature appeared to have a large effect on O&G solubility, with the higher temperature samples having time step-averaged equilibrium concentrations 3 to 5 times higher than the lower temperature samples.

A comparison of the VOCs and O&G measured in groundwater at the site to the concentration determined by the LNAPL solubility testing is shown in Table 2 (attached at end of the TM). There was significant variability between the concentrations observed in the groundwater compared to LNAPL solubility test samples. The groundwater O&G concentrations were 10 to 20 percent of the time step- and temperature-averaged O&G concentrations in solubility test samples. This is to be expected since field solubilization is typically much less effective than lab testing methods. To the contrary, however, the time step- and temperature-averaged benzene concentration in groundwater (maximum 96 µg/L in PZ-10) was higher than the solubility test sample results (maximum 82 µg/L in PZ-10). These concentrations of benzene, however, are more than four orders-of-magnitude lower than the pure chemical solubility of benzene (TPHCWG, 1999) and approximately one order-of-magnitude lower than the reported theoretical solubility of benzene in fresh diesel fuel (Zemo, 2006). Therefore, the results are likely a function of intrinsic heterogeneity rather than a sign of LNAPL-bias in the groundwater samples or non-equilibrium conditions in the solubility test samples.

After the separation period, the aqueous phase from the pH-adjusted samples had a much milkier, less clear appearance than the non-pH adjusted samples from the same location. However, the concentrations were nearly identical between the two sets of samples, indicating that pH did not play a significant role in LNAPL solubility. The pH of the unadjusted sample from PZ-14 was 6.10.

The concentrations of VOCs and O&G determined by the LNAPL solubility testing are considered to be representative of site-specific limits of LNAPL solubility. If concentrations of these constituents in groundwater samples approach these "threshold" concentrations, then presence of LNAPL in the soil is likely.

6. Soil Solidification/Stabilization (S/S) Testing

Soil S/S testing was performed on samples from three different locations at the site to determine the optimal dose of Portland Cement (PC) that should be added to stabilize free liquids in excavated soils and allow them to be transported and disposed of at offsite facilities.

6.1 Sample Preparation and Characterization

Six soil samples were received at ASL, from two different positions at three site locations. These samples were shipped to ASL in 2 gallon plastic "paint buckets". Upon receipt at the lab, each sample was mixed with a clean large metal spoon to create six mixtures that were each as homogenous as possible. Initial characterization samples of each mixture were collected for analysis of free liquids by the paint filter test method and characterization of pH, moisture content, and O&G.

6.2 Test Setup

All samples failing the initial paint filter test were selected for S/S testing with PC. Each sample was split into four subsamples, and each subsample received a different dose of PC. The low dose was 5 percent PC, the medium-low dose was 10 percent PC, the medium-high dose was 15 percent PC, and the high dose was 20 percent PC, on a dry soil weight basis.

The test procedure is summarized below, and setup data are shown in Table 3 (attached at end of the TM).

1. 250 g (as-received wet weight) of each homogenous sub-sample was added to a 1 L glass beaker
2. The desired PC dose was added to each beaker
3. The soil and PC were thoroughly mixed with a clean stainless steel spoon
4. All setup data was recorded
5. The beakers of amended soil were allowed to stand uncovered at room temperature for one day to set/cure
6. Each amended beaker was remixed and aliquots were collected for analysis of pH, moisture content, and free liquids by the paint filter test

6.3 Results

As shown in Table 3 (attached at end of the TM), both samples from BSTP-SS-WL passed the initial paint filter test and were excluded from S/S testing. The low PC dose of 5 percent by dry weight was sufficient to tie up free liquids and allow each amended sample to pass the paint filter test. It is possible that a lower of PC could be used. However, the 5 percent dose will allow some additional contingency should wetter conditions be encountered.

7. Biocell Treatment Phase I Testing

The first phase of aerobic biocell testing (Phase I) is being conducted on soil considered to represent High-level of LNAPL contamination as defined using the approach and field methods described in Section 4. Phase I is being performed with the objective of investigating the applicability limits of the biocell technology as well as to gather overall information on its applicability to site conditions. Of note, in the ROD and FFS, provisions were included to allow for excavation and offsite disposal of these soils.

The test is being performed using bench-scale static soil columns with induced airflow through the beds to maintain aerobic conditions. Multiple columns are being tested to evaluate the effects of different soil amendments. System operation and performance are being evaluated by periodic collection and analysis of soil and off-gas samples. Phase I also tests various amendments that could enhanced the performance of the technology.

7.1 Setup

On November 12, 2010, five biocell columns were set up based on the test conditions summarized in Table 4.

TABLE 4
Summary Biocell Treatment Phase I Test Conditions
Diamond Head Superfund Site

Test ID	Description	Amendment(s)
BIOCELL-1	Intrinsic control	None
BIOCELL- 2	Unamended	Air, water
BIOCELL- 3	Bulking & nutrients	Air, water, bulking agent, nutrients
BIOCELL- 4	Bulking, nutrients, & pH adjustment	Air, water, bulking agent, nutrients, pH adjustment
BIOCELL- 5	Bulking, nutrients, pH adjustment, & substrate	Air, water, bulking agent, nutrients, pH adjustment, organic amendment and bioaugmentation

The soil used in the columns was composited in the laboratory to create, to the extent practical, a single homogeneous sample for the test. Oversized rocks and debris were removed by hand. Aliquots of the soil sample for Phase I ("characterization samples" as referenced in the test plan) were collected, composited, and analyzed as described in the test plan (CH2M HILL, 2010b). Phase I (High) soil characterization test results are summarized in Table 5 (attached at end of the TM).

The biocell test columns consisted of 6 inch diameter, clear polyvinyl chloride (PVC) columns containing 4 feet (bed depth) of soil. The columns were capped on each end and equipped with inlets, outlets, and ports to allow introduction of air, discharge of off-gas and leachate; and collection of soil, offgas, and leachate (if any accumulates) samples for analysis.

Column loading details are presented in Attachment A, Table A-1 (attached at end of the TM). During setup, initial (time zero) soil samples were collected for analysis (see Table 6, reproduced from the test plan, attached at end of the TM).

After time zero sampling and column setup, testing was initiated on the afternoon of November 12, 2010 by starting air flow to the soil beds of Columns 2 through 5.

7.1.1 Column Setup Notes

Bulking agent – Wood chips were obtained from a source local to the lab consisting of rough ground yard debris waste (with chips ranging up to two inches in length). This was believed to be consistent with the possibility of using ground trees from the site as a bulking agent. A 5 to 1 mix (soil to wood chips by volume) was determined to be the minimum amount of wood chips needed to visually bulk the soil such that it appeared that air permeability would be increased. Wood chips were added to the soil used for Columns 3, 4, and 5.

Compaction – 85 percent of the maximum Standard Proctor dry bulk density was determined to be 73.7 lb/ft³ for the unbulked soil and 68.6 lb/ft³ for the bulked soil based on preliminary testing at ASL (see Tables A-2 and A-3, attached at end of the TM). Note that soil samples were also submitted to a separate geotechnical laboratory for analysis. Each of the columns was packed in a series of 6 inch lifts. The mass of soil required for each 6-inch

lift (bulked or unbulked) was added to each column and packed to the appropriate level before proceeding to the next lift.

pH – The pH of the as-received soil was found to be very alkaline with a pH of approximately 12.8 as measured in the characterization sample¹. In order to attempt to reduce the pH into a range more favorable for microbial degradation it was decided to add aluminum sulfate ($\text{Al}_2[\text{SO}_4]_3$), a common agricultural amendment. A pH titration was performed (see Table A-4, attached at end of the TM), and a rate of 88 pounds of aluminum sulfate per ton of dry soil was determined to be necessary to achieve a pH of 7 in titration experiments. The solid aluminum sulfate was added to each lift during setup for Columns 4 and 5.

Nutrients (N and P) – N and P were added at a rate of 250 mg N and 100 mg P per kg of dry soil as NH_4Cl and Na_2HPO_4 as per oily waste composting guidance available from Chevron Research and Technology Company. The salts were dissolved in water and added to each lift of soil in Columns 3, 4, and 5.

Organic amendment and bioaugmentation – Column 5 had separate organic and bioaugmentation amendments added per lift. OilBuster®, a solid mixture of ground corncob and approximately 100 micron diameter spherical bee/soy wax (http://www.unireminc.com/prp_powder.html), was added as an organic amendment per vendor recommendations at a rate 16 g per kg of dry soil (1:1 by mass total TPH). MicroBlaze®, a liquid mixture of surfactant, nutrients, and bacteria (<http://www.micro-blaze.com/products/micro-blaze-emergency-liquid-spill-control>), was added as a bioaugmentation source per vendor recommendations at a rate 1 gallon of 3 percent solution per 10 cubic yards of soil.

Air flow rate – Air flow was started at approximately 5 mL/min and shortly thereafter raised to approximately 10 mL/min. Air flow from the column off-gas is measured using a Gillibrator® air flow meter. At this flow rate, the air flow can be consistently provided to Columns 2, 3, 4, and 5 using a peristaltic pump with stacked cassette heads. At this flow the pressure measured in the column air supply lines ranges from approximately 3 to 28 inches of water column. Additionally, a measurable drop in oxygen concentration was observed across the columns with the effluent oxygen not typically dropping below 17% at this point in time. In order to prevent drying of the soil over time, the influent air is humidified by bubbling through water before pumping through the columns.

7.2 Results

The Phase I columns have now been in operation for 4½ months. Samples were collected per the test plan requirements (Table 6, attached at end of the TM) at time zero, Month 1, and Month 2 of operation. The analytical results are summarized in Table 7 (attached at end of the TM). The Month 3 and Month 4 sampling events were postponed to allow more time for biodegradation of the highly contaminated soil to occur in order to improve the chances of observing a measurable decrease in hydrocarbon concentrations.

7.2.1 Soil Sampling

¹ The presence of numerous pale yellow rocks of various sizes was observed during homogenization of the soil and packing the columns. The composition of the yellow rocks is not known at this time. However, when a few of these rocks were placed in a beaker of Milli-Q water, the resulting pH was in the 12-13 range.

The pH in the columns remained high over the sampling durations. The unadjusted columns (Columns 1-3) all had pH values around 12.6 measured in all three sampling events. The pH adjusted Columns (4 and 5) appeared to have slightly decreased pH values between 11 and 12 at times, but the aluminum sulfate addition did not achieve the desired pH neutralization as the titration tests suggested it would. It is suspected that the calculated dose of aluminum sulfate required per unit mass of soil determined in the titration experiment did not account for alkaline minerals that are slow to dissolve (the titration results are included in Table A-4, attached at end of the TM). The soil likely contains such alkaline minerals that overwhelmed the aluminum sulfate added to the columns over time.

The extractable petroleum hydrocarbon (EPH, C10-C40) concentrations did not change significantly over the first two months of column operation. EPH in some of the columns decreased slightly from time zero to Month 2, while some of the columns appeared to increase slightly. Given the high initial concentration of EPH in the columns, a relatively small biodegradation of EPH is not sufficient to overcome the inherent heterogeneity of hydrocarbons in the soil material. Assuming biodegradation was not significant enough in the short two month period, it is important to note that the standard deviation of the EPH concentrations appears to span a range of approximately +/- 14 percent of the mean value. This essentially means that biodegradation would need to degrade at least 28 percent of the initially present EPH mass in order for the reduction to be measurable outside the range of soil variability.

The volatile petroleum hydrocarbon (VPH) concentrations appeared to increase over the first two months of column operation in all columns, including the stagnant control. The percentage increases from time zero to Month 1 and from Month 1 to Month 2 are nearly identical in all five columns. Communications are in progress with the laboratory subcontracted to perform the VPH analysis to verify the possibility of the consistent increase being a laboratory artifact. It is interesting to note that comparison of BTEX and naphthalene concentrations as measured by EPA Method 8260 at time zero to those reported as part of the VPH analysis indicates that the time zero and Month 1 VPH results may have been biased low.

Similar to the LNAPL solubility test results discussed in Section 5.2, the SGT removed a significant fraction of plant and animal oils and fats from the total O&G by EPA Method 1664; the petroleum-contaminant-related fraction of O&G ranged from 46 to 86 percent of the total O&G. This indicates that SGT is a necessary component of the O&G analytical procedure to ensure that natural materials are removed. The remainder of this analysis focuses on O&G with SGT results.

The O&G with SGT concentrations were also virtually unchanged over the first two months of column operations, with slight changes in concentration that fell within the range of natural variability. The heterogeneity of the O&G with SGT is similar to the EPH which means that biodegradation would need to degrade at least 26-percent of the initially present O&G with SGT mass in order for a sample result to be meaningful and lie outside the range of soil heterogeneity. As expected, the presence of bee/soy wax in Column 5 resulted in an increased concentration of O&G in comparison to the other columns, but the SGT appears to have eliminated the bias. The average O&G with SGT concentration from the three monitoring events is identical in Columns 4 and 5.

Nutrient and moisture content analyses over the first two months of operation show that the columns were within the range of operating parameters specified in the test plan.

7.2.2 Leachate Monitoring

The production of leachate from the columns has not occurred thus far. This is because the columns are maintained in an unsaturated state (near 75% of field capacity) in order to allow air to easily pass through. Any increase in water content would decrease air permeability such that adequate air flow would not be achieved in the columns. The addition of more water to the columns to create leachate would, at the same time, detrimentally affect airflow and treatment efficiency. Therefore, it was decided that leachate quality data would be collected by the addition of selected analytes specified for leachate on Table 6 (attached at end of the TM) to the SPLP extract from the routine column soil samples. The SPLP extract from the composite soil samples is taken to be representative of the leachate that might be generated from the biocell.

The time zero SPLP results from the soil indicated visible oil sheen in all columns except Column 5. The lack of sheen of Column 5 may have been related to the presence of bee/soy wax in the OilBuster® which strongly sorbs LNAPL or the surfactant present in the MicroBlaze® which would increase the solubility of the LNAPL. Some VOCs (i.e., toluene, xylene, 1,2,4-trimethylbenzene, and naphthalene) were detected in the SPLP extract, but were only slightly above method reporting limits and none exceeded NJDEP Class IIA groundwater criteria. Unlike the LNAPL solubility test results, no benzene, PCE, TCE, cis-1,2-DCE, or VC were detected in the SPLP extract. The lack of increased detections in VOC concentrations in SPLP leachate from Column 5 suggests that the MicroBlaze® surfactant had little if any effect on the solubility of VOCs.

7.2.3 Offgas Monitoring

The column offgas has been monitored approximately twice per week using a portable meter since the test began to check for leaks and/or other problems and to monitor oxygen utilization in the columns. Offgas monitoring results to date are summarized in Table 8 (attached at end of the TM).

Methane has been regularly detected by the portable meter in all five columns within the range of 100 to 500 ppmv. The columns receiving airflow were expected to be aerobic and therefore were not expected to be producing significant amounts of methane. To further investigate the issue of apparent methane production, an offgas split sample from Column 5 was analyzed by EPA Method RSK-175 (gas chromatography [GC]). GC analysis of the sample collected on January 7, 2011 showed that methane was below the method reporting limit of 100 ppmv, while the meter was reading 400 ppmv. This confirms that the methane readings reported by the portable meter are predominantly a response to other combustible gasses (such as BTEX) and are not representative of actual methane concentrations in the offgas.

The RSK-175 analysis on Column 5 offgas also confirmed that the carbon dioxide concentration was below the method reporting limit of 100 ppmv. This supported the consistent response of the portable meter indicating that carbon dioxide in the offgas was less than 100 ppmv. Furthermore, this result confirmed that the offgas carbon dioxide was less than the ambient atmospheric concentration (approximately 390 ppmv), indicating that the highly alkaline soil is scrubbing carbon dioxide from the offgas.

The oxygen concentrations in Columns 2-5 are lower than in the no-flow control column, and all columns are below the typical ambient concentration of oxygen in the laboratory of 20.9 percent. The average oxygen utilization rates over the last month of operation are summarized in Table 9.

TABLE 9.
Average Oxygen Utilization (2/21/11 through 3/21/11)
Diamond Head Superfund Site

	Column 1	Column 2	Column 3	Column 4	Column 5
Oxygen Offgas Concentration (%)	20.3	19.7	19.6	18.9	17.5
Oxygen Utilization (%)	0.63	1.2	1.3	2.0	3.4
Oxygen Utilization (%/h)	0.049	0.089	0.10	0.16	0.26

The oxygen utilization rates increase with increasing degree of amendments, with Column 5 having the highest oxygen utilization. With the exception of the first few weeks after startup, the oxygen utilization rates have been fairly consistent over the 4½ month test duration (Table 8, attached at end of the TM). Overall, the consistent concentrations of oxygen in the offgas over time and the relative rates of oxygen utilization between columns is indicative of enhanced biological activity. The highest rate of oxygen utilization is occurring in Column 5 which included bioaugmentation, addition of an external carbon source, and the addition of nutrients.

The oxygen utilization rate in Column 5 was calculated as the decrease in oxygen across the column (offgas minus influent) divided by the residence time of the air within the column (approximately 13 hours) and was found to be approximately 0.3%/hour.

This is within the range of oxygen utilization rates for biodegradation of petroleum hydrocarbons across a range of contaminated sites calculated by Hinchee and Ong (1992). The eight sites covered by their study showed biodegradation-associated oxygen utilization rates ranging from 0.02% to 0.99% per hour. It should be noted that the Hinchee and Ong results were obtained from in situ studies, whereas these results were performed in a biocell with many of the columns having several optimizations over in situ conditions. However, Column 2 was set up in such a way as to simulate in situ conditions and the oxygen utilization rate was still within the range observed by Hinchee and Ong despite the very high pH and concentrations of hydrocarbons.

The oxygen utilization rates can be used to estimate hydrocarbon biodegradation and concentration reductions over time based on stoichiometry.

Table A-5 (attached at end of the TM) includes a calculation of the theoretical amount of hydrocarbons predicted to be remaining after 2 and 12 months. The calculation assumes a 9,000 mg/kg starting hydrocarbon concentration, taken from total VPH/EPH for Column 5 from Table 7 (attached at end of the TM). Assuming the existing oxygen utilization rate is constant, the estimated concentration of hydrocarbon remaining after 2 months is approximately 8,500 mg/kg. This represents only a 5% decrease and, as discussed in Section 7.2.1, would likely not be possible to distinguish from the inherent variability in the soil data.

However, after 12 months, the remaining concentration is estimated to be about 6,200 mg/kg, which represents a 30% decrease and would reside just outside the estimated range of observed heterogeneity in the soil.

Assuming the existing oxygen utilization rate is constant for the duration of the project, the stoichiometric model indicates that the hydrocarbons would be completely removed after 3-4 years. It should be noted that Column 5 was amended with a small amount of organic substrate, and the substrate may have initially contributed to the oxygen utilization. However, the quantity of biodegraded hydrocarbon now exceeds the mass of substrate loaded into the columns and the current utilization could be assumed to be from contaminant biodegradation.

As a point of reference, if the oxygen utilization rate for Column 4 is used in the spreadsheet in Table A-5 (attached at end of the TM), the remaining hydrocarbon after 12 months would be 7,400 mg/kg and biodegradation may not be discernable because the concentration would lie within the range of intrinsic soil variability.

7.3 Microbial Sampling

Given the high pH and hydrocarbon concentrations in the Phase 1 soil columns, the question was raised as to whether environmental conditions were so extreme as to prevent the development of a viable aerobic-functioning microbial population. In order to address this concern, a direct measurement of the microbial population in the soil in select columns was performed.

More details of the microbial sampling and analysis effort can be found in the *Draft Technical Memorandum Summary of Microbial Sampling Procedures and Results* (CH2M HILL, March 16, 2011).

7.3.1 Data Objectives

Various microbiological tools were considered for this application. It was determined that basic plate counts would not provide as much information as the more recently developed methods like PLFA, denaturing gradient gel electrophoresis (DGGE), and quantitative polymerase chain reaction (qPCR). qPCR is a highly specific method that was deemed inappropriate for this project at this stage because specific target organisms have not yet been identified that match the contaminant and bioremediation process being undertaken in the column study. PLFA was determined to be the best choice as a first step because it can provide viable biomass quantification (key decision driver), community diversity (basic groups), and physiological status (health). Most importantly, PLFA would provide a total cell count of the microbes in the column soil. Additionally, the breakdown of basic microbial groups will help provide insight as to whether the MicroBlaze® microbes (amended to Column 5) took hold and are healthy, or whether indigenous microbes appeared to be the predominant active strains.

7.3.2 Sampling Activities and Laboratory Analyses

The soil samples were collected from various sampling ports along the length of each column, composited, and shipped on ice to Microbial Insights in Rockford, Tennessee for PLFA analysis. Soil sampling was conducted on February 16, 2011, and consisted of the collection of samples from the sources listed on Table 10.

TABLE 10
Microbial Sampling Summary
Diamond Head Superfund Site

Sample	Distinguishing Column Operating Condition
Column 2	Air only
Column 4	Air, wood chips, nutrients, pH adjustment
Column 5	Air, wood chips, nutrients, pH adjustment, Oil Buster®, and MicroBlaze®
MicroBlaze®	A sample of the raw undiluted product (liquid mixture of surfactant, nutrients, and bacteria)

The MicroBlaze® product sample was submitted to assess if the microbial populations established in Column 5 were derived from the MicroBlaze®. Duplicate samples were collected and analyzed from Columns 4 and 5.

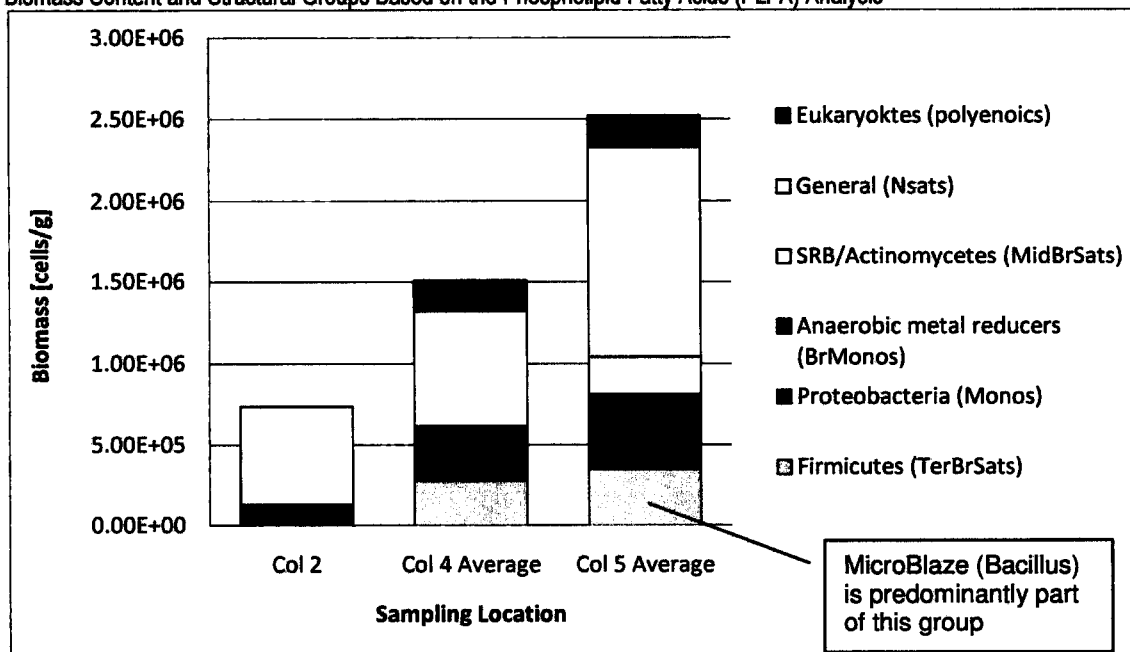
7.3.3 Summary of Results

Laboratory results were received from Microbial Insights on March 10, 2011. The biomass results are summarized in Table 11 and Figure 2.

TABLE 11
Biomass Content and Structural Groups Based on the Phospholipid Fatty Acids (PLFA) Analysis
Diamond Head Superfund Site

Parameter	Col 2	Col 4 Average	Col 5 Average	MicroBlaze
Units	cells/g	cells/g	cells/g	cells/mL
Total biomass	7.34E+05	1.51E+06	2.52E+06	1.19E+06
<i>Component Biomass</i>				
Firmicutes (TerBrSats)	0	2.75E+05	3.51E+05	1.06E+06
Proteobacteria (Monos)	1.27E+05	3.39E+05	4.58E+05	1.96E+04
Anaerobic metal reducers (BrMonos)	0	0	0	2.74E+03
SRB/Actinomycetes (MidBrSats)	0	0	2.32E+05	0
General (Nsats)	6.07E+05	7.03E+05	1.29E+06	9.19E+04
Eukaryoktes (polyenoics)	0	1.87E+05	1.92E+05	1.74E+04

FIGURE 2
Biomass Content and Structural Groups Based on the Phospholipid Fatty Acids (PLFA) Analysis



Total Biomass

The overall abundance of microbes within a given sample is often used as an indicator of the potential for bioremediation to occur. Microbial Insights suggests the following benchmarks that can be used to understand whether the biomass levels are low, moderate or high:

Low – 10^3 to 10^4 cells per gram (cells/g)

Moderate – 10^5 to 10^6 cells/g

High – 10^7 to 10^8 cells/g

Some key observations related to total biomass include:

- Moderate levels of viable biomass were present in all soil samples: Column 2 (7.34×10^5 cells/g), Column 4 (1.51×10^6 cells/g average), and Column 5 (2.52×10^6 cells/g average).
- Columns 4 and 5 had 2.1 and 3.4 times more viable biomass, respectively, than Column 2 which indicates that the wood chips, nutrients, and/or pH adjustment had a positive effect.
- Column 5 had approximately 1.7 times more viable biomass than Column 4 which indicates that the MicroBlaze had an additional positive effect.
- The roughly doubling of biomass from Column 2 to Column 4, and doubling again from Column 4 to Column 5, is very similar to the trend in oxygen utilization

(Table 9). This is supportive of the observed oxygen utilization being biologically induced.

Structural Groups

Some key observations related to structural groups include:

- The MicroBlaze sample indicates that viable biomass primarily shows up in the Firmicutes (TerBrSats) structural group. This group is where Microbial Insights had indicated that *Bacillus* would show up, which is the primary strain of bacteria contained in MicroBlaze. Bacilli are facultative aerobes, which means they can adapt to various conditions, aerobic or anaerobic. Microbial Insights reports that they do not typically see Firmicutes at such high percentage of the total microbial community.
- Firmicutes and Eukaryotes exist in both Columns 4 and 5 and indicate that they are naturally present – possibly from the wood chips since Column 2 showed none.
- The population of Firmicutes is larger in the bioaugmented Column 5 by approximately 30%.
- Both Firmicutes (Columns 4 and 5) and Actinomycetes (Column 5) communities include aerobes and anaerobes. So, the community structure results confirm the higher population of aerobes in Columns 4 and 5. Of note is that the Actinomycetes (MidBrSats) are what sets Column 5 apart from the remaining columns, and these were not found in the MicroBlaze raw material. This suggests that it is the surfactant or other components of the MicroBlaze combined with the added sulfate and/or Oil Buster that stimulated indigenous Actinomycetes in Column 5. Mid-chain branched saturates (MidBrSats) are common in Actinomycetes microorganisms.

7.4 Geotechnical Sampling

The results of the soil samples submitted to GeoTesting Express, Inc geotechnical laboratory for analysis are summarized in Attachment A, Table A-6 (attached at end of the TM). These data were obtained for use in construction of the biocell in the field and for confirmation of preliminary measurements made at ASL prior to column setup. They are not further discussed in this TM.

8. Biocell Treatment Phase II

The soil for Phase II of the biocell treatment testing was excavated from areas of low and medium contamination soil trenches using visual means as discussed in Section 4. The second phase of testing will be used to test the “best” (highest efficiency) test conditions identified in Phase I testing on soils representing relatively light and moderate levels of contamination.

8.1 Characterization

The low and medium Phase II soil was composited in the laboratory to create, to the extent practical, a single homogeneous sample for the test. Efforts were made to mimic mixing processes that would be utilized in full-scale application. Aliquots of the soil samples for Phase II (“characterization samples” as referenced in the test plan) were collected,

composited, and analyzed as described in the test plan. Standard Proctor compaction and water holding capacity tests were not performed, as the samples were assumed to be similar enough to the Phase I soils not to warrant these analyses. The pH titration curve was not performed pending a go/no-go decision on setting up Phase II column tests, and the question as to whether pH adjustment of the soil is feasible. The characterization test results (Phase II Med and Low) are summarized in Table 5 (attached at end of the TM).

The soil pH in the medium and low samples was 9.98 and 10.2, respectively. These pH values are still higher than optimal for microbial growth and activity (pH range 5-9), but are significantly lower than the Phase I soil. The moisture content of the medium and low soils is approximately 2/3 to half that of the Phase I soils, indicating that some additional moisture may need to be added during setup to optimize Phase II operation.

The VOC concentrations measured in the medium soil are approximately an order of magnitude lower than those measured in the Phase I High soils. The O&G and diesel- and oil-range TPH concentrations are higher in the Medium soil, however, than in the Phase I soil, and indicates the limitations of visual methods to screen hydrocarbon concentrations in the field.

The VOCs concentrations in the low soils are nearly two orders of magnitude lower than those measured in the Phase I High soils. The O&G and all TPH fraction concentrations are also lower.

Assuming the heterogeneity is similar to the Phase I High soils, the reduced initial concentrations of hydrocarbons in the Phase II soils indicate that biodegradation is much more likely to be measurably demonstrated over a relatively short test duration than was possible for the Phase I soils.

[Placeholder for new results. Lab results for EPH, VPH, and SPLP are expected on April 3. Table 5 will be revised and sent out once the data are received.]

9. Conclusions

The results of the LNAPL solubility, soil S/S, and the Phase I biocell treatment testing are summarized below in the context of the original test objectives.

9.1 LNAPL Solubility

- The objective of determining the water solubility of LNAPL from various locations across the site, measured as a concentration of oil and grease (O&G), was achieved.
- Relatively constant O&G with SGT concentrations were measured in the LNAPL solubility samples across the range of mixing times and at multiple pH values.
- The second objective of determining the effective solubility of selected VOCs in water that is in direct contact with LNAPL was also achieved.
- Relatively constant VOC concentrations were measured in the LNAPL solubility samples across the range of mixing times and at multiple pH values.
- Achieving both of these objectives allowed for determination of a "threshold" value for O&G with SGT. This threshold value of 8 mg/L for O&G with SGT is indicative of where a sheen may be present.

9.2 Soil Solidification/Stabilization (S/S) Testing

- The objective of determining the amount of PC that must be blended with a given quantity of soil to absorb the free liquids and allow the sample to pass the paint filter test was achieved by the S/S testing.
- The testing showed that a PC dose of 5 percent would absorb the free liquids in all samples and allow them to pass the paint filter test.
- It is possible that less PC may be used to stabilize the soil. However, if field conditions differ slightly from those tested in the laboratory, then the 5 percent dose may add an additional factor of safety.

9.3 Biocell Treatment Testing

- The objective of assessing the treatment effectiveness for the monitored contaminants has not been achieved to date.
- Due to the inherent heterogeneity of hydrocarbons in the soil and the high initial hydrocarbon concentrations, no biodegradation of the monitored compounds was observed over the first two months that was outside of the range of hydrocarbon variability in the soil samples.
- Based on the observed oxygen utilization rates and the calculated stoichiometric biodegradation rates, no change in hydrocarbon concentration outside the estimated range of observed variability in the soil is expected until after 12 months or more of column operation.
- The objective of determining the "best" combination of amendments (pH adjustment, bulking agent, nutrients, and bioenhancement) has been partially achieved.
- Columns 4 and 5 have shown oxygen utilization rates significantly higher than those observed in Columns 1 through 3, indicating that pH control measures in addition to oxygen and bulking material amendments lead to better column performance. However, the pH values measured in Columns 4 and 5 are still outside the range of values for optimal microbial growth.
- Column 5 has demonstrated higher oxygen utilization rates than Column 4, indicating that the addition of organic amendment and bioaugmentation may lead to more ideal conditions in the biocell. However, because some of the initial oxygen utilization in Column 5 may have been due to the organic amendment addition, it is not possible to discern from the current data whether this additional amendment has enhanced hydrocarbon degradation.
- The objective of determining oxygen uptake rates was achieved.
- The oxygen uptake rates ranged from 0.049%/hr in the stagnant control to 0.26 %/hr in column 5. The rates, particularly in Columns 4 and 5, were within ranges previously observed for aerobic biodegradation of petroleum contaminated soil and indicated increased biological activity in the amended columns.

- The objective of evaluating leachate quality was only partially achieved.
- As discussed in section 7.2.2, no actual leachate was produced from the columns. However, SPLP extract from the column soil samples at time zero was used as a surrogate to simulate leachate that would be expected to be produced by the biocell. This leachate is considered worst case because it would be leaching off the untreated soil at the beginning of biocell operations. The later leachate analysis planned for the end of Month 4 has been postponed, so no evaluation of leachate from partially treated soil can be made at this time.
- The objective of evaluating gaseous emissions has been achieved.
- Oxygen, combustible gas, and carbon dioxide concentrations in the offgas have been monitored over the duration of column operation, and VOC and TPH concentrations in offgas were analyzed at time zero and after Months 1 and 2. The offgas VOC and TPH concentrations have remained fairly constant over the first two months of operation, with no concentration changes outside the range of observed variability.

10. Path Forward Discussion

The results of the Phase I biocell treatment testing thus far are not 100 percent conclusive. Two of three lines-of-evidence suggest the feasibility of this technology to treat the contaminated soil onsite, but the last, and most important, is not yet clear. A summary of the three primary lines of evidence used to assess the effectiveness of biodegradation for treatment of the contaminants at the site is provided below:

- **Oxygen utilization** – Oxygen utilization rates are established and within the normal range of what has been observed at other petroleum hydrocarbon contaminated sites. The oxygen utilization rates are not as high as may be expected under optimal conditions in the laboratory and are suggestive of an operation and maintenance period within a time-frame of several years.
- **Viable microbial biomass** – Despite the high pH and hydrocarbon concentrations present in the Phase I soil, moderate levels of a viable microbial community were confirmed in all columns, including the control. The total viable biomass measured in each of the columns was proportional to the observed oxygen utilization rates, which is supportive of the presence of active aerobic microbial activity.
- **Hydrocarbon degradation** – Measurable decreases of petroleum hydrocarbons have not been confirmed as of the last sampling event (Month 2). However, stoichiometric calculations show that given the high levels of hydrocarbons present in the Phase I soil, measurable decreases may not be expected for up to a year of operation.

The Phase II soil characterization results indicate that the low and medium soils have a substantially lower pH than the Phase I (high) soil. Additionally, the hydrocarbon concentrations of the Low soil (and some hydrocarbon components of the Medium soil) are also much lower than the Phase I soil. These factors may result in higher hydrocarbon degradation rates for the Low and Medium soils than observed for the Phase I High soils,

thereby improving the likelihood of measurable hydrocarbon degradation over the planned test duration (4 months).

11. References

CH2M HILL, 2010, "Treatability Study Test Plan for the Diamondhead Superfund Site," August 26, 2010.

CH2M HILL, 2010b, "OU1 LNAPL Source Area Bench Scale Sample Collection Field Documentation," October 18, 2010.

CH2M HILL, 2011. "Draft Technical Memorandum Summary of Microbial Sampling Procedures and Results," March 16, 2011.

Hinchee, R.E. and Ong, S.K., 1992, "A Rapid In Situ Respiration Test for Measuring Aerobic Biodegradation Rates of Hydrocarbons in Soil," *Journal of the Air and Waste Management Association*, 42(10):1305-1312.

Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG), 1999. Volume 5: Human-Health Risk-Based Evaluation of Petroleum Release Sites: Implementing the Working Group Approach. Prepared by D.J. Vorhees, W.H. Weisman, and J.B. Gustafson. June 1999. Zemo, D.A., 2006. Sampling in the Smear Zone: Evaluation of Nondissolved Bias and Associated BTEX, MTBE, and TPH Concentrations in Ground Water Samples. *Ground Water Monitoring and Remediation*, Vol. 26, No. 3, Summer 2006, pp 125-133.

TABLE 1

Test Pit Observation Log

Diamond Head Superfund Site

Key Observed Subsurface Materials and/or Field Observations									
Test Pit	Product or Produced Strained Material (approximate depth observed, ft bgs)	Product Odor Observed (approximate depth observed, ft bgs)	Concrete Surface/ Refusal Depth (approximate refusal depth, ft bgs)	Debris (wood, brick pieces, concrete pieces, boulders, etc.) (approximate depth observed, ft bgs)	Potential Petroleum Waste Sludge Material (approximate depth observed, ft bgs)	White Clay-like Material (approximate depth observed, ft bgs)	NAPL Seep Entering Test Pit (approximate depth observed, ft bgs)	Reddish-purple and Olive-yellow Clay-like Material (approximate depth observed, ft bgs)	Sample Collected
H-1	Not Observed	5.5-11.5	Not Observed	Not Observed	Not Observed	Not Observed	Not Observed	Not Observed	High
H-2	8.0-12.0	5.0-12.0	Not Observed	8.0-11.5	11.5-12.0	Not Observed	6.5	Not Observed	High
H-3	Not Observed	7.0-12.0	Not Observed	7.0-11.5	11.5-12.0	Not Observed	Not Observed	Not Observed	High
H-4	7.0-8.0, 9.0-9.5	6.5-10.5	Not Observed	3.0-4.0, 9.0-9.5	9.5-10.0	Not Observed	6.5	7.9-9.0	High
H-5	6.5-10.0	6.4-10.0	Not Observed	Not Observed	10.0-10.5	Not Observed	Not Observed	Not Observed	High
H-6	Not Observed	Not Observed	3.0	Not Observed	Not Observed	Not Observed	Not Observed	Not Observed	High
H-7	Not Observed	Not Observed	3.5	Not Observed	Not Observed	Not Observed	Not Observed	Not Observed	High
H-8	5.5-10.0	5.5-11.0	Not Observed	6.0-10.0	10.0-11.0	Not Observed	Not Observed	Not Observed	Low
L-1	Not Observed	8.5-9.5	Not Observed	Not Observed	Not Observed	Not Observed	Not Observed	Not Observed	Low
L-2	Not Observed	Not Observed	Not Observed	Not Observed	7.3-9.0	5.5-6.75	Not Observed	Not Observed	Low
L-3A	Not Observed	Not Observed	7.0	Not Observed	Not Observed	Not Observed	Not Observed	Not Observed	Low
L-3B	Not Observed	Not Observed	6.0	Not Observed	Not Observed	Not Observed	Not Observed	Not Observed	Low
L-3C	Not Observed	3.0-9.0	3.9	Not Observed	10.8-11.5	Not Observed	Not Observed	2.5-3.0	Low
L-4	8.0-12.0	8.0-12.0	Not Observed	8.0-12.0	12.0-12.5	Not Observed	9.0	Not Observed	Low
M-1	Not Observed	2.0-10.0	Not Observed	Not Observed	Not Observed	Not Observed	Not Observed	Not Observed	Med
M-2	Not Observed	1.0-9.0	Not Observed	7.5-8.0	8.0-9.0	Not Observed	Not Observed	Not Observed	Med
M-3	6.0-9.5	6.0-12.0	Not Observed	0.0-6.0	Not Observed	Not Observed	6.5	Not Observed	Med
M-4	Not Observed	Not Observed	3.5	Not Observed	Not Observed	Not Observed	Not Observed	Not Observed	Med
M-5	Not Observed	Not Observed	3.5	Not Observed	Not Observed	Not Observed	Not Observed	Not Observed	Med
M-6	Not Observed	Not Observed	3.5	0.5-3.5	Not Observed	Not Observed	Not Observed	Not Observed	Med
M-7	Not Observed	Not Observed	3.5	Not Observed	Not Observed	Not Observed	Not Observed	Not Observed	Med
M-8	8.0-12.0	5.0-12.0	Not Observed	8.0-11.5	Not Observed	Not Observed	6.0	Not Observed	Med
M-10	Not Observed	2.5-9.0	Not Observed	0.0-2.5	11.5-12.0	6.0-6.5	Not Observed	Not Observed	Med
SS-NA-1	Not Observed	Not Observed	2.5	Not Observed	Not Observed	Not Observed	Not Observed	Not Observed	S/S Testing
SS-NA-2	3.0-5.0	2.0-5.0	5.0	2.0-5.0	Not Observed	Not Observed	Not Observed	Not Observed	S/S Testing
SS-NA-3	Not Observed	Not Observed	6.0	Not Observed	Not Observed	Not Observed	Not Observed	Not Observed	S/S Testing
SS-NA-4	Not Observed	Not Observed	6.5	Not Observed	Not Observed	Not Observed	Not Observed	Not Observed	S/S Testing
SS-SA	6.0-8.2	6.0-8.2	2.0-2.5, 8.2	7.0-8.2	Not Observed	Not Observed	7.0	Not Observed	S/S Testing
SS-WL	0.3-3.0	0.3-3.0	Not Observed	Not Observed	0.3-3.0	Not Observed	Not Observed	Not Observed	S/S Testing

TABLE 2
LNAPL Solubility Testing Results
Diamond Head Superfund Site

Parameter Units		NJ Class IIA	Ground water	LNAPL + Milli-Q Water@15 °C				LNAPL + Milli-Q Water@21 °C				LNAPL + Milli-Q Water@21 °C, pH Adjusted			
				18 hours	42 hours	66 hours	Time Step Average	18 hours	42 hours	66 hours	Time Step Average	18 hours	42 hours	66 hours	Time Step Average
PZ-10															
VOCs*															
Vinyl Chloride	ug/L	0.08	21	5.00 U	5.00 U	5.00 U	5.00 U	3.55	4.49	5.00 U	4.35	--	--	--	--
Acetone		6000	100 U	39.8	35.1	36.3	37.1	47.0	65.1	10.0 U	40.7	--	--	--	--
1,1-Dichloroethane		50	3.7 J	5.50	5.18	5.00 U	5.23	6.28	7.89	6.98	7.05	--	--	--	--
2-Butanone (MEK)		300	100 U	10.0 U	10.0 U	10.0 U	10.0 U	5.00 U	5.00 U	10.0 U	6.67 U	--	--	--	--
cis-1,2-Dichloroethene		70	96	118	110	110	113	138	167	147	151	--	--	--	--
Benzene		1	97	76.6	69.0	64.6	70.1	81.6	61.5	69.5	70.9	--	--	--	--
Trichloroethene (TCE)		1	10 U	5.00 U	5.00 U	5.00 U	5.00 U	2.50 U	2.50 U	5.00 U	3.33 U	--	--	--	--
4-Methyl-2-pentanone (MIBK)			100 U	10.0 U	10.0 U	10.0 U	10.0 U	5.99	8.00	10.0 U	8.00	--	--	--	--
Toluene		600	180	304	256	230	263	251	53.4	262	189	--	--	--	--
1,3-Dichloropropane			NA	5.00 U	5.00 U	5.00 U	5.00 U	2.95	2.50 U	5.00 U	3.48	--	--	--	--
Tetrachloroethene (PCE)		1	10 U	5.00 U	5.00 U	5.00 U	5.00 U	2.50 U	2.50 U	5.00 U	3.33 U	--	--	--	--
Chlorobenzene		50	10 U	5.00 U	5.00 U	5.00 U	5.00 U	2.50 U	2.50 U	5.00 U	3.33 U	--	--	--	--
Ethylbenzene		700	92	39.6	42.8	41.2	41.2	2.50 U	2.50 U	51.2	18.7	--	--	--	--
m,p-Xylene		1000	200	279	248	279	269	252	248	383	294	--	--	--	--
o-Xylene		1000	190	182	174	179	178	216	239	243	233	--	--	--	--
Isopropylbenzene		700	10 U	5.00 U	5.00 U	5.25	5.08	5.46	2.86	9.15	5.82	--	--	--	--
n-Propylbenzene			NA	5.74	7.65	9.55	7.65	2.50 U	2.50 U	17.0	7.33	--	--	--	--
1,3,5-Trimethylbenzene			NA	39.9	40.1	49.8	43.3	58.7	68.3	85.0	70.7	--	--	--	--
1,2,4-Trimethylbenzene			NA	163	150	195	169	120	103	306	176	--	--	--	--
1,4-Dichlorobenzene		75	10 U	5.00 U	5.00 U	5.00 U	5.00 U	3.28	3.20	5.00 U	3.83	--	--	--	--
p-Isopropyltoluene			NA	5.00 U	5.00 U	5.00 U	5.00 U	4.54	5.45	8.93	6.31	--	--	--	--
1,2-Dichlorobenzene		600	27	24.7	24.0	24.7	24.5	29.1	31.6	33.8	31.5	--	--	--	--
1,2,4-Trichlorobenzene		9	10 U	5.00 U	5.00 U	5.00 U	5.00 U	2.50 U	2.50 U	5.00 U	3.33 U	--	--	--	--
Naphthalene		300	NA	117	108	112	112	89.0	90.1	148	109	--	--	--	--
Visual O&G		Not Observed	Yes	No	No	No	No	Yes	No	No	Yes	--	--	--	--
O&G	mg/L		28.1	25.0	64.7	211	100	68.7	135.0	716	307	--	--	--	--
O&G w/ SGT	mg/L		NA	14.1	45.9	157	72.3	51.3	80.7	545	226	--	--	--	--

TABLE 2
LNAPL Solubility Testing Results
Diamond Head Superfund Site

ParameterUnits		NJ Class IIA	Ground water	LNAPL + Milli-Q Water@15 °C				LNAPL + Milli-Q Water@21 °C				LNAPL + Milli-Q Water@21 °C, pH Adjusted			
				18 hours	42 hours	66 hours	Time Step Average	18 hours	42 hours	66 hours	Time Step Average	18 hours	42 hours	66 hours	Time Step Average
MW-13S															
VOCs*		ug/L													
Vinyl Chloride			0.08	5.0 U	5.00 U	5.00 U	5.00 U	1.10 U	1.10 U	1.10 U	1.10 U	--	--	--	--
Acetone			6000	50 U	53.9	56.0	58.6	56.2	2.20 U	2.20 U	62.3	22.2	--	--	--
1,1-Dichloroethane			50	19	5.16	5.34	5.27	5.26	6.32	6.20	5.80	6.11	--	--	--
2-Butanone (MEK)			300	50 U	10.0 U	10.0 U	10.0 U	10.0 U	2.20 U	2.20 U	2.20 U	2.20 U	--	--	--
cis-1,2-Dichloroethene			70	5.0 U	5.00 U	5.00 U	5.00 U	5.00 U	1.10 U	1.10 U	1.10 U	1.10 U	--	--	--
Benzene			1	60	18.6	18.9	18.5	18.7	21.6	21.2	19.8	20.9	--	--	--
Trichloroethene (TCE)			1	5.0 U	5.00 U	5.00 U	5.00 U	5.00 U	1.10 U	1.10 U	1.10 U	1.10 U	--	--	--
4-Methyl-2-pentanone (MIBK)				50 U	10.0 U	10.0 U	10.0 U	10.0 U	2.20 U	2.20 U	2.20 U	2.20 U	--	--	--
Toluene			600	27	28.2	28.5	27.5	28.1	32.6	32.3	29.5	31.5	--	--	--
1,3-Dichloropropane				NA	5.00 U	5.00 U	5.00 U	5.00 U	1.10 U	1.10 U	1.10 U	1.10 U	--	--	--
Tetrachloroethene (PCE)			1	5.0 U	5.00 U	5.00 U	5.00 U	5.00 U	1.10 U	1.10 U	1.10 U	1.10 U	--	--	--
Chlorobenzene			50	18	11.8	12.0	11.9	11.9	13.3	12.9	12.0	12.7	--	--	--
Ethylbenzene			700	4.8 J	7.11	6.97	6.77	6.95	8.91	8.75	8.00	8.55	--	--	--
m,p-Xylene			1000	89	61.8	102	97.2	87.0	126	122	110	119	--	--	--
o-Xylene			1000	97	69.8	73.9	70.2	71.3	88.2	84.8	77.7	83.6	--	--	--
Isopropylbenzene			700	5.0 U	5.00 U	5.00 U	5.00 U	5.00 U	6.93	6.69	5.72	6.45	--	--	--
n-Propylbenzene				NA	12.0	11.7	11.9	11.9	18.9	17.5	14.5	17.0	--	--	--
1,3,5-Trimethylbenzene				NA	13.0	12.8	13.1	13.0	20.4	18.6	15.8	18.3	--	--	--
1,2,4-Trimethylbenzene				NA	42.3	83.7	86.5	70.8	125	114	97.6	112	--	--	--
1,4-Dichlorobenzene			75	5.0 U	5.00 U	5.00 U	5.00 U	5.00 U	4.00	3.71	3.37	3.69	--	--	--
p-Isopropyltoluene				NA	5.00 U	5.00 U	5.00 U	5.00 U	2.25	1.80	1.38	1.81	--	--	--
1,2-Dichlorobenzene			600	36	35.0	35.6	35.6	35.4	41.6	39.6	35.9	39.0	--	--	--
1,2,4-Trichlorobenzene			9	5.0 U	5.00 U	5.00 U	5.00 U	5.00 U	1.96	1.58	1.32	1.62	--	--	--
Naphthalene			300	NA	64.1	58.0	59.2	60.4	74.8	70.7	64.7	70.1	--	--	--
Visual O&G			Not Observed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	--	--	--
O&G		mg/L		19.9	37.6	31.2	55.4	41.4	140	292	42.4	158	--	--	--
O&G w/ SGT		mg/L		NA	21.0	23.1	37.0	27.0	103	223	20.5	116	--	--	--

TABLE 2
LNAPL Solubility Testing Results
Diamond Head Superfund Site

Parameter	Units	NJ Class IIA	Ground water	LNAPL + Milli-Q Water@15 °C				LNAPL + Milli-Q Water@21 °C				LNAPL + Milli-Q Water@21 °C, pH Adjusted			
				18 hours	42 hours	66 hours	Time Step Average	18 hours	42 hours	66 hours	Time Step Average	18 hours	42 hours	66 hours	Time Step Average
PZ-14															
VOCs*	<i>ug/L</i>														
Vinyl Chloride		0.08	10 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U
Acetone		6000	890	74.5	83.5	98.7	85.6	63.5	86.2	88.2	79.3	63.7	66.4	90.9	73.7
1,1-Dichloroethane		50	4.3 J	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U
2-Butanone (MEK)		300	100 U	10.0 U	10.0 U	10.0 U	10.0 U	15.2	10.0 U	10.0 U	11.7	10.0 U	10.0 U	21.3	13.8
cis-1,2-Dichloroethene		70	20	37.0	41.3	42.0	40.1	38.6	38.0	42.1	39.6	37.8	37.2	39.6	38.2
Benzene		1	67	51.7	65.0	26.4	47.7	69.1	70.6	79.4	73.0	68.7	65.2	73.0	69.0
Trichloroethene (TCE)		1	7.5 J	10.5	10.9	12.0	11.1	11.5	11.3	12.9	11.9	11.4	10.7	11.5	11.2
4-Methyl-2-pentanone (MIBK)			1,600	376	422	418	405	379	375	405	386	10.0 U	369	422	267
Toluene		600	160	95.5	185	12.9	97.8	243	233	274	250	217	176	253	215
1,3-Dichloropropane			NA	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U
Tetrachloroethene (PCE)		1	1.2 J	5.00 U	5.00 U	6.27	5.42	5.00 U	5.00 U	5.43	5.14	5.00 U	5.00 U	5.42	5.14
Chlorobenzene		50	10 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U
Ethylbenzene		700	47	5.00 U	11.3	5.00 U	7.10	75.1	75.8	99.7	83.5	63.0	6.96	93.8	54.6
m,p-Xylene		1000	150	230	238	336	268	242	228	306	259	220	221	292	244
o-Xylene		1000	110	162	170	234	189	169	161	207	179	158	155	200	171
Isopropylbenzene		700	2.4 J	5.25	6.78	6.27	6.10	6.44	7.28	11.9	8.54	5.75	5.00 U	11.4	7.38
n-Propylbenzene			NA	5.00 U	5.00 U	5.00 U	5.00 U	18.6	17.9	36.3	24.3	13.5	5.00 U	34.0	17.5
1,3,5-Trimethylbenzene			NA	47.2	54.0	107.0	69.4	41.9	41.9	76.9	53.6	34.0	34.2	74.4	47.5
1,2,4-Trimethylbenzene			NA	278	308	559	382	257	224	406	296	195	203	398	265
1,4-Dichlorobenzene		75	10 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U
p-Isopropyltoluene			NA	6.72	7.83	19.9	11.5	5.00 U	5.08	13.4	7.83	5.00 U	5.00 U	13.4	7.80
1,2-Dichlorobenzene		600	13	19.1	20.5	29.6	23.1	17.8	5.00 U	5.00 U	9.27	17.9	17.3	25.0	20.1
1,2,4-Trichlorobenzene		9	10 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U
Naphthalene		300	NA	147	166	243	185	146	141	201	163	131	128	198	152
Visual O&G		Not Observed	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No
O&G	<i>mg/L</i>		25.5	217.0	46.9	56.2	107	36.0	49.3	1120	402	42.8	43.9	254	114
O&G w/ SGT	<i>mg/L</i>		NA	147	23.3	23.7	64.7	12.1	18.5	859	297	36.9	15.9	185	79.3

Notes:

Bolded values represent detected concentrations exceeding NJ Class IIA

*No other VOCs were detected above their respective Method Reporting Limits (MRLs) in the LNAPL solubility sample:

U = Not detected at the specified method reporting limit

J = Detected - concentration estimated

NA = Not Analyzed

TABLE 3**S/S Testing Results***Diamond Head Superfund Site*

	PC Dose	pH	Moisture Content	Paint Filter Test	Oil and Grease
Sample	% (dry wt basis)	Standard units	%		mg/kg
BSTP-SS-WL-01	as received	11	48.6	Pass	535,700
BSTP-SS-WL-02	as received	10.8	47.7	Pass	566,100
BSTP-SS-SA-01	as received	9.43	31.1	Fail	55,940
	5	12.2	23.5	Pass	--
	10	12.6	21.6	Pass	--
	15	12.7	19.8	Pass	--
	20	12.7	18.5	Pass	--
BSTP-SS-SA-02	as received	9.41	30.5	Fail	69,390
	5	12.4	16.8	Pass	--
	10	12.6	21.0	Pass	--
	15	12.6	21.8	Pass	--
	20	12.7	15.9	Pass	--
BSTP-SS-NA-01	as received	10.5	26.1	Fail	32,920
	5	12.6	22.3	Pass	--
	10	12.6	16.4	Pass	--
	15	12.7	19.8	Pass	--
	20	12.7	18.3	Pass	--
BSTP-SS-NA-02	as received	9.25	45.1	Fail	115,000
	5	12.4	23.9	Pass	--
	10	12.6	21.5	Pass	--
	15	12.6	24.3	Pass	--
	20	12.6	21.8	Pass	--

TABLE 5

Characterization Results - Phase I and Phase II

Diamond Head Superfund Site

Parameter	Method	Units	Phase I (High)	Phase II (Med)	Phase II (Low)
Soil					
pH	EPA 9045	std units	12.8	9.98	10.2
Moisture content	EPA 160.3	%	35.3	23.1	17.1
VOCs*	EPA 8260	µg/kg			
Acetone			1,280	312 U	19.5 U
Benzene			204 U	156 U	1.95 U
Trichloroethene (TCE)			204 U	156 U	1.95 U
4-Methyl-2-pentanone (MIBK)			748	312 U	9.75 U
Toluene			2,290	291	1.95 U
Tetrachloroethene (PCE)			325	156 U	1.95 U
Ethylbenzene			1,600	753	13.4
m,p-Xylene			6,840	2,820	3.90 U
o-xylene			3,810	2,710	70.6
Isopropylbenzene			422	393	10.8
n-Propylbenzene			1,390	1,150	41.6
1,3,5-Trimethylbenzene			3,910	2,570	269
1,2,4-Trimethylbenzene			13,200	9,680	13.8
sec-Butylbenzene			443	397	23.7
1,4-Dichlorobenzene			204 U	156 U	18.1
p-Isopropyltoluene			749	576	67.1
1,2-Dichlorobenzene			876	682	120
n-Butylbenzene			1,900	156 U	195
1,2,4-Trichlorobenzene			325	162	14.1
Naphthalene			5,010	3,320	29.0
NJDEP EPH	SW846 3545	µg/kg			
1,2,3-Trimethylbenzene			--		
Acenaphthylene			--		
Acenaphthene			--		
Fluorene			--		
Phenanthrene			--		
Anthracene			--		
Fluoranthene			--		
Pyrene			--		
Benzo (a) anthracene			--		
Chrysene			--		
Benzo (b) fluoranthene			--		
Benzo (k) fluoranthene			--		
Benzo (a) pyrene			--		
Indeno (1,2,3-cd) pyrene			--		
Dibenzo (a,h) anthracene			--		
Benzo (g,h,i) perylene			--		
C10-C12 Aromatics			70,200		
C12-C16 Aromatics			95,600		
C16-C21 Aromatics			451,000		
C21-C36 Aromatics			1,290,000		
Total Aromatics			1,900,000		
C9-C12 Aliphatics			160,000		
C12-C16 Aliphatics			226,000		
C16-C21 Aliphatic			684,000		
C21-C40 Aliphatics			4,410,000		
Total Aliphatics			5,480,000		
Total EPH ¹			7,380,000		

TABLE 5

Characterization Results - Phase I and Phase II

Diamond Head Superfund Site

Parameter	Method	Units	Phase I (High)	Phase II (Med)	Phase II (Low)
MADEP VPH	REV 1.1	µg/kg			
Benzene			310 U		
Ethylbenzene			1,580		
Methyl Tert Butyl Ether			63 U		
Naphthalene			4,390		
Toluene			2,340		
m,p-Xylene			5,860		
o-Xylene			3,200		
C5- C8 Aliphatics (Unadj.) ²			12,400		
C9- C12 Aliphatics (Unadj.) ²			85,800		
C9- C10 Aromatics (Unadj.) ²			52,200		
C5- C8 Aliphatics ²			9,910		
C9- C12 Aliphatics ²			23,000		
Total VPH ¹			150,400		
Total VPH/EPH		µg/kg	7,530,400		
O&G	EPA 9071B	mg/kg	34,826	68,600	7,700
O&G w/ SGT	EPA 9071B	mg/kg	20,215	43,600	7,230
TPH-g	EPA8015	mg/kg	578	155	25.3
TPH-d	EPA8015	mg/kg	6,900	20,700	2,440
TPH-o	EPA8015	mg/kg	9,090	41,800	3,910
Water holding capacity	in-house method	%	43.67	--	--
Standard Proctor Compaction	ASTM D698	lb/ft3	86.7	--	--
Simulated Leachate - SPLP from Soil					
SPLP-VOCs**	EPA 8260	µg/L			
Acetone			50.0 U		
Benzene			25.0 U		
Trichloroethene (TCE)			25.0 U		
4-Methyl-2-pentanone (MIBK)			50.0 U		
Toluene			31.9		
Tetrachloroethene (PCE)			25.0 U		
Ethylbenzene			25.0 U		
m,p-Xylene			57.9		
o-Xylene			25.0 U		
Isopropylbenzene			25.0 U		
n-Propylbenzene			25.0 U		
1,3,5-Trimethylbenzene			25.0 U		
1,2,4-Trimethylbenzene			73.6		
sec-Butylbenzene			25.0 U		
1,4-Dichlorobenzene			25.0 U		
p-Isopropyltoluene			25.0 U		
1,2-Dichlorobenzene			25.0 U		
n-Butylbenzene			25.0 U		
1,2,4-Trichlorobenzene			25.0 U		
Naphthalene			28.0		
SPLP-O&G		mg/L	89.9		
SPLP-O&G w/ SGT		mg/L	62.6		
SPLP Visual O&G - Sheen Observed			Yes		

Notes:

*No other VOCs were detected above their respective Method Reporting Limits (MRLs)

**Same analytes shown as for soil analyses

¹ "Total VPH" is the sum of C5- C8 Aliphatics (Unadj.); C9- C12 Aliphatics (Unadj.); and C9- C10 Aromatics (Unadj.) .

"Total EPH" is as reported by the laboratory.

² These five analytes are as reported by the laboratory. "(Unadj.)" refers to the fact that the analyte was not adjusted to exclude the individual volatile compounds reported immediately above.

EPH, VPH, and SPLP parameters for Phase I were obtained during column setup at Month 0.

U = Not detected at the specified method reporting limit

TABLE 6

Biocell Test Monitoring Plan

Diamond Head Superfund Site

Parameter	Time [months]					Total per column	Total for all Phase 1 columns	Total for all Phase 2 columns
	0	1	2	3	4			
Soil							5 columns	3 columns
pH	3	1	1	1	3	9	45	27
VOCs (BTEXN)	1				1	2	10	6
O&G (with silica gel cleanup)	3	1	1	1	3	9	45	27
NJ EPH (fractionation with silica gel cleanup)	1	1	1	1	1	5	25	15
MA VPH (fractionation with silica gel cleanup)	1	1	1	1	1	5	25	15
Moisture content	3	1	1	1	3	9	45	27
SPLP-VOCs	1				1	2	10	6
SPLP-O&G (with silica gel cleanup)	1				1	2	10	6
Nutrients	1	1	1	1	1	5	25	15
Temperature	1	1	1	1	1	5	25	15
Off-gas							4 columns*	3 columns
O ₂	1	6	4	2	2	14	56	42
CO ₂	1	6	4	2	2	14	56	42
VOCs (BTEXN)	1	2	2	1	1	6	24	18
TPH	1	2	2	1	1	6	24	18
O ₂ uptake and CO ₂ production rate	1	2	2	1	1	6	24	18
Leachate							5 columns	3 columns
Total Cd, Cu, Pb, Ni, Zn		1			1	2	10	6
Total Hg		1			1	2	10	6
BOD		1	1	1	1	4	20	12
TSS		1	1	1	1	4	20	12
pH		1	1	1	1	4	20	12
O&G (with silica gel cleanup)		1	1	1	1	4	20	12
NJ EPH (fractionation with silica gel cleanup)		1	1	1	1	4	20	12
MA VPH (fractionation with silica gel cleanup)		1	1	1	1	4	20	12
NH ₃ -N		1	1	1	1	4	20	12
NO ₃ -N		1	1	1	1	4	20	12
PO ₄ -P		1	1	1	1	4	20	12
VOCs (full list for TTO)		1			1	2	5	6
SVOCs		1			1	2	5	6
Pesticides/PCBs		1			1	2	5	6

Numbers in Soil schedule mean no. of samples collected at the end of the specified month; 3's mean replicate samples; 1's indicate single composite samples.

Numbers in Off-gas schedule mean no. of samples collected during the specified month of operation (approximately evenly spaced in time). For example, 4 means once per week.

Numbers in Leachate schedule mean no. of samples collected during the specified month of operation. Timing depends on generation of sufficient leachate volume for analysis.

* No off-gas monitoring done for Intrinsic Control column because no air flow.

VOCs, SVOCs, & Pesticides/PCBs = Total Toxic Organics (TTO)

BTEXN = benzene, toluene, ethylbenzene, xylenes, and naphthalene

TABLE 7
Phase 1 Biocell Results Summary
Diamond Head Superfund Site

Parameter	Units	BIOCELL-P1-1			BIOCELL-P1-2			BIOCELL-P1-3			BIOCELL-P1-4			BIOCELL-P1-5		
		0 month	1 month	2 month	0 month [†]	1 month	2 month	0 month	1 month	2 month	0 month	1 month	2 month	0 month	1 month	2 month
Soil		11/12/2010	12/10/2010	1/7/2011	11/12/2010	12/10/2010	1/7/2011	11/12/2010	12/10/2010	1/7/2011	11/12/2010	12/10/2010	1/7/2011	11/12/2010	12/10/2010	1/7/2011
pH	Standard Units	12.6	12.5	12.6	12.6	12.6	12.7	12.6	12.6	12.6	11.1	12.5	11.0	12.3	11.0	11.9
Moisture Content	%	34.3	33.1	25.1	34.3	33.9	30.5	32.8	32.6	34.6	36.9	35.4	32.8	36.2	31.0	35.0
Temperature	Celsius	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
VOCs	ug/kg															
Acetone		2,950	--	--	2,950	--	--	2,690	--	--	1,490	--	--	2,230	--	--
Benzene		365	--	--	365	--	--	315	--	--	210 U	--	--	375	--	--
Trichloroethene (TCE)		327	--	--	327	--	--	318	--	--	210 U	--	--	345	--	--
4-Methyl-2-pentanone (MIBK)		1,440	--	--	1,440	--	--	1,200	--	--	836	--	--	1,320	--	--
Toluene		5,420	--	--	5,420	--	--	5,420	--	--	3,130	--	--	5,490	--	--
Tetrachloroethene (PCE)		623	--	--	623	--	--	564	--	--	392	--	--	619	--	--
Ethylbenzene		3,550	--	--	3,550	--	--	3,720	--	--	2,500	--	--	4,170	--	--
m,p-Xylene		14,100	--	--	14,100	--	--	14,500	--	--	9,600	--	--	14,400	--	--
o-Xylene		8,270	--	--	8,270	--	--	8,250	--	--	5,820	--	--	9,720	--	--
Isopropylbenzene		691	--	--	691	--	--	911	--	--	694	--	--	1,070	--	--
n-Propylbenzene		2,970	--	--	2,970	--	--	3,050	--	--	2,370	--	--	3,360	--	--
1,3,5-Trimethylbenzene		7,340	--	--	7,340	--	--	7,300	--	--	5,790	--	--	7,570	--	--
1,2,4-Trimethylbenzene		25,300	--	--	25,300	--	--	24,400	--	--	22,200	--	--	26,000	--	--
sec-Butylbenzene		858	--	--	858	--	--	923	--	--	750	--	--	1,020	--	--
1,4-Dichlorobenzene		240	--	--	240	--	--	221	--	--	210 U	--	--	271	--	--
p-Isopropyltoluene		1,320	--	--	1,320	--	--	1,240	--	--	1,150	--	--	1,450	--	--
1,2-Dichlorobenzene		1,990	--	--	1,990	--	--	1,790	--	--	1,400	--	--	2,250	--	--
n-Butylbenzene		3,790	--	--	3,790	--	--	3,480	--	--	3,220	--	--	3,900	--	--
1,2,4-Trichlorobenzene		681	--	--	681	--	--	480	--	--	517	--	--	597	--	--
Naphthalene		12,100	--	--	12,100	--	--	11,900	--	--	9,090	--	--	11,800	--	--
NIDEF EPH SW846 3545	ug/kg															
C10-C12 Aromatics		70,200	67,300	66,500	70,200	62,100	83,800	39,500	70,600	91,000	70,700	77,200	90,200	56,100	72,200	95,200
C12-C16 Aromatics		95,600	103,000	110,000	95,600	82,600	134,000	56,300	91,700	145,000	109,000	107,000	134,000	87,900	111,000	140,000
C16-C21 Aromatics		451,000	452,000	413,000	451,000	333,000	518,000	247,000	344,000	536,000	481,000	459,000	518,000	395,000	544,000	508,000
C21-C36 Aromatics		1,290,000	1,270,000	1,200,000	1,290,000	907,000	1,750,000	742,000	993,000	1,790,000	1,270,000	1,190,000	1,710,000	968,000	1,340,000	1,550,000
Total Aromatics		1,900,000	1,890,000	1,790,000	1,900,000	1,380,000	2,490,000	1,080,000	1,500,000	2,570,000	1,930,000	1,830,000	2,450,000	1,510,000	2,070,000	2,290,000
C9-C12 Aliphatics		160,000	146,000	129,000	160,000	167,000	160,000	118,000	166,000	171,000	223,000	151,000	199,000	196,000	225,000	180,000
C12-C16 Aliphatics		226,000	266,000	233,000	226,000	244,000	284,000	180,000	250,000	285,000	378,000	252,000	332,000	333,000	347,000	310,000
C16-C21 Aliphatic		684,000	780,000	645,000	684,000	661,000	796,000	527,000	682,000	734,000	1,060,000	710,000	880,000	982,000	911,000	796,000
C21-C40 Aliphatics		4,410,000	4,330,000	3,980,000	4,410,000	3,680,000	4,610,000	3,750,000	4,050,000	4,450,000	5,580,000	3,890,000	5,050,000	5,360,000	4,810,000	4,600,000
Total Aliphatics		5,480,000	5,520,000	4,990,000	5,480,000	4,750,000	5,850,000	4,580,000	5,150,000	5,640,000	7,250,000	5,000,000	6,460,000	6,870,000	6,300,000	5,890,000
Total EPH ¹		7,380,000	7,410,000	6,770,000	7,380,000	6,130,000	8,340,000	5,660,000	6,650,000	8,210,000	9,180,000	6,830,000	8,910,000	8,370,000	8,370,000	8,180,000
MADEP VPH REV 1.1	ug/kg															
Benzene		310 U	470 U	684	310 U	400 U	843	360 U	540 U	852	370 U	460 U	786	330 U	570 U	869
Ethylbenzene		1,580	2,770	3,480	1,580	3,060	4,070	1,520	3,750	4,650	1,570	3,180	3,560	1,460	3,420	4,750
Methyl Tert Butyl Ether		63 U	94 U	97 U	63 U	80 U	94 U	72 U	110 U	110 U	74 U	91 U	110 U	65 U	110 U	110 U
Naphthalene		4,390	12,800	12,500	4,390	12,400	12,100	4,060	17,000	14,700	4,520	13,000	11,900	4,180	14,600	14,800
Toluene		2,340	2,900	3,350	2,340	3,600	3,940	2,410	3,800	4,930	2,310	3,800	3,640	2,050	4,350	5,340
m,p-Xylene		5,860	7,690	9,040	5,860	8,870	10,600	5,510	10,700	13,400	5,620	8,980	10,100	5,130	9,970	14,300
o-Xylene		3,200	4,980	6,690	3,200	5,510	7,970	3,090	6,740	9,440	3,230	5,450	7,080	2,940	6,280	9,480
C5- C8 Aliphatics (Unadj.) ²		12,400	27,900	56,100	12,400	29,900	63,200	11,100	37,500	60,300	10,500	32,800	57,700	10,800	46,100	73,500
C9- C12 Aliphatics (Unadj.) ²		85,800	224,000	362,000	85,800	218,000	374,000	76,100	293,000	382,000	83,900	229,000	359,000	81,500	326,000	419,000
C9- C10 Aromatics (Unadj.) ²		52,200	132,000	232,000	52,200	132,000	260,000	46,500	179,000	286,000	51,600	141,000	252,000	50,000	192,000	295,000
C5- C8 Aliphatics ²		9,910	24,700	52,000	9,910	26,000	58,400	8,500	33,400	54,500	7,980	28,600	53,200	8,650	41,200	67,200
C9- C12 Aliphatics ²		23,000	77,400	112,000	23,000	68,500	91,900	19,500	93,200	68,400	21,900	70,100	86,900	22,000	115,000	94,600
Total VPH ¹		150,400	383,900	650,100	150,400	379,900	697,200	133,700	509,500	728,300	146,000	402,800	668,700	142,300	564,100	787,500
Total VPH/EPH	ug/kg	7,530,400	7,793,900	7,420,100	7,530,400	6,509,900	9,037,200	5,793,700	7,159,500	8,938,300	9,326,000	7,232,800	9,578,700	8,512,300	8,934,100	8,967,500
O&G	ug/kg	32,600,000	44,900,000	44,800,000	32,600,000	38,200,000	44,900,000	34,800,000	30,800,000	41,600,000	36,800,000	34,200,000	37,300,000	44,600,000	34,900,000	42,700,000
O&G w/ SGT	ug/kg	27,900,000	26,700,000	30,600,000	27,900,000	26,600,000	29,800,000	26,700,000	23,600,000	29,100,000	25,150,000	24,600,000	24,300,000	34,250,000	24,400,000	19,700,000
Nutrients	mg/kg															
Nitrate	as N	3.63	3.24	4.38	3.63	4.33	4.88	4.05	3.83	3.85	1.59 U	1.57 U	1.51 U	1.70	1.45 U	1.54 U
Phosphate	total as P	357 *	465	156	357 *	220	249	428 *	286	326	362 *	265	207	247 *	274	206
Ammonia	as N	59.1	47.1	47.4	59.1	57.4	54.3	211	178	200	236	162	156	204	113	131

TABLE 7
Phase 1 Biocell Results Summary
Diamond Head Superfund Site

Parameter	Units	BIOCELL-P1-1			BIOCELL-P1-2			BIOCELL-P1-3			BIOCELL-P1-4			BIOCELL-P1-5		
		0 month	1 month	2 month	0 month*	1 month	2 month	0 month	1 month	2 month	0 month	1 month	2 month	0 month	1 month	2 month
Simulated Leachate - SPLP from Soil																
SPLP-VOCs	ug/L															
Acetone		50.0 U	--	--	50.0 U	--	--	50.0 U	--	--	50.0 U	--	--	50.0 U	--	--
Benzene		25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--
Trichloroethene (TCE)		25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--
4-Methyl-2-pentanone (MIBK)		50.0 U	--	--	50.0 U	--	--	50.0 U	--	--	50.0 U	--	--	50.0 U	--	--
Toluene		31.9	--	--	31.9	--	--	30.7	--	--	25.0 U	--	--	26.1	--	--
Tetrachloroethene (PCE)		25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--
Ethylbenzene		25.0 U	--	--	25.0 U		--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--
m,p-Xylene		57.9	--	--	57.9	--	--	56.5	--	--	50.0 U	--	--	58.0	--	--
o-Xylene		25.0 U	--	--	25.0 U	--	--	35.9	--	--	25.0 U	--	--	35.3	--	--
Isopropylbenzene		25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--
n-Propylbenzene		25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--
1,3,5-Trimethylbenzene		25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--
1,2,4-Trimethylbenzene		73.6	--	--	73.6	--	--	71.6	--	--	55.7	--	--	77.7	--	--
sec-Butylbenzene		25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--
1,4-Dichlorobenzene		25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--
p-Isopropyltoluene		25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--
1,2-Dichlorobenzene		25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--
n-Butylbenzene		25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--
1,2,4-Trichlorobenzene		25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--	25.0 U	--	--
Naphthalene		28.0	--	--	28.0	--	--	28.0	--	--	25.0 U	--	--	29.0	--	--
SPLP-O&G	mg/L	89.9	--	--	89.9	--	--	15.1	--	--	33.7	--	--	47.1	--	--
SPLP-O&G w/ SGT	mg/L	62.6	--	--	62.6	--	--	12.3	--	--	22.6	--	--	26.6	--	--
Visual O&G - Sheen Observed		Yes	--	--	Yes	--	--	Yes	--	--	Yes	--	--	No	--	--
Off-gas		11/23/2010	12/10/2010	1/7/2011	11/23/2010	12/10/2010	1/7/2011	11/23/2010	12/10/2010	1/7/2011	11/23/2010	12/10/2010	1/7/2011	11/23/2010	12/10/2010	1/7/2011
Portable Meter Results																
Air flow rate	mL/min	0	0	0	8.2	10.3	9.72	9.1	9.2	9.38	9.9	10.2	10.32	10.4	10.9	9.71
Oxygen	%	19.6	20.9	20.8	20.4	20.6	20.2	19.6	20.4	20.2	19.8	20.0	19.3	18.2	17.7	17.2
Carbon dioxide	ppmv	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U
Carbon monoxide	ppmv	12	10	0	1 U	2	0	24	30	5	18	17	10	22	24	10
Combustible gasses	ppmv as CH4	540	450	220	440	450	310	920	740	350	640	560	310	620	680	400
VOCs																
Acetone	ppbv	--	--	--	15,900 E	11,600 E	4,490	46,000 E	10,500 E	13,500 E	19,600 E	4,170 E	220	16,900 E	5,610 E	7,220 E
Benzene		--	--	--	664	800	601	1,100	581	550	706	288	560	699	264	413
Trichloroethene (TCE)		--	--	--	201	266	163	280	147	140	187	97	132	224	75	123
4-Methyl-2-pentanone (MIBK)		--	--	--	1,120	753	279	910	100	1,120	809	21.8 U	41.8 U	1,130	293	587
Toluene		--	--	--	3,290	4,660	4,070	4,380	2,430	3,450	3,090	1,300	2,690	3,950	1,160	2,490
Tetrachloroethene (PCE)		--	--	--	202	258	242	283	156	205	199	85	190	254	79	181
Ethylbenzene		--	--	--	1,070	1,370	1,270	1,240	657	1,160	1,060	260	755	1,220	376	974
m,p-Xylene		--	--	--	3,000	4,330	4,090	3,280	2,020	3,650	2,900	969	2,230	3,510	1,130	2,870
o-Xylene		--	--	--	1,530	2,260	2,090	1,600	1,090	1,950	1,510	446	1,250	1,800	664	1,750
Isopropylbenzene		--	--	--	202	240	224	219	123	221	206	27	122	267	76.0	201
n-Propylbenzene		--	--	--												
1,3,5-Trimethylbenzene		--	--	--	560	678	681	498	285	686	505	61	315	701	208	688
1,2,4-Trimethylbenzene		--	--	--	1,200	1,480	1,580	498	546	1,690	1,040	128	676	1,440	475	1,580
sec-Butylbenzene		--	--	--	82.3	80.7	85.2	77.1	30.0	86.3	75.0	21.8 U	41.8 U	101	27.7	82.2
1,4-Dichlorobenzene		--	--	--	74.0 U	74.0 U	67.0 U	68.3 U	27.6 U	52.0 U	53.3 U	21.8 U	41.8 U	67.7 U	12.5 U	33.5 U
p-Isopropyltoluene		--	--	--	76.1	75.0	84.2	95.6	27.6 U	90.4	74.5	21.8 U	48.8	98.3	27.2	90.3
1,2-Dichlorobenzene		--	--	--	74.0 U	74.0 U	67.0 U	68.3 U	27.6 U	52.0 U	53.3 U	21.8 U	41.8 U	67.7 U	12.5 U	33.5 U
n-Butylbenzene		--	--	--	74.0 U	74.0 U	67.0 U	68.3 U	27.6 U	75.6	53.3 U	21.8 U	41.8 U	67.7 U	19.9	78.7
1,2,4-Trichlorobenzene		--	--	--	74.0 U	74.0 U	67.0 U	68.3 U	27.6 U	52.0 U	53.3 U	21.8 U	41.8 U	67.7 U	12.5 U	33.5 U
Naphthalene		--	--	--	148 U	148 U	134 U	137 U	55.2	104 U	107 U	43.6 U	83.6 U	135 U	25.0 U	67.0 U
TPH-g	ug/L	--	--	--	602	528	513	716	497	469	668	411	605	717	449	452
RSK-175																
Carbon dioxide	ppmv	--	--	--	--	--	--	--	--	--	--	--	--	--	--	100 U
Methane		--	--	--	--	--	--	--	--	--	--	--	--	--	--	100 U

Notes:

- Duplicate results shown when two values are reported
Number in *italics* represent the average of multiple results.
U = Not detected at the specified method reporting limit
- 1 "Total VPH" is the sum of C5- C8 Aliphatics (Unadj.); C9- C12 Aliphatics (Unadj.); and C9- C10 Aromatics (Unadj.) . "Total EPH" is as reported by the laboratory.
2 These five analytes are as reported by the laboratory. "(Unadj.)" refers to the fact that the analyte was not adjusted to exclude the individual volatile compounds reported immediately above.
+ At time zero BIOCELL-1 and BIOCELL-P1-2 were identical samples. One sample was submitted for both.
- * Analyzed outside of holdings times

TABLE 8

Portable Meter Periodic Offgas Monitoring Results
Diamond Head Superfund Site

Parameter	Units	BIOCELL-P1-1	BIOCELL-P1-2	BIOCELL-P1-3	BIOCELL-P1-4	BIOCELL-P1-5
11/14/2010						
Flow rate	mL/min	--	--	--	--	--
Combustible Gasses (as CH4)	ppm	0	0	0	0	0
O2	%	20.1	19.2	19.3	20.5	20.8
CO	ppm	12	53	35	12	0
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	17.75	16.5	5.0	3.5
11/19/2010						
Flow rate	mL/min	--	10.28	8.55	9.89	10.77
Combustible Gasses (as CH4)	ppm	--	500	940	530	910
O2	%	20.9	20.5	20.6	19.9	12.9
CO	ppm	--	0	4	23	32
CO2	ppm	--	0	0	0	0
ΔP	in H2O	--	--	--	--	--
11/20/2010						
Flow rate	mL/min	--	10.5	8.79	9.68	9.92
Combustible Gasses (as CH4)	ppm	--	320	1050	600	710
O2	%	--	20.1	19.1	19.2	18.2
CO	ppm	--	4	27	20	29
CO2	ppm	--	0	0	0	0
ΔP	in H2O	--	--	--	--	--
11/22/2010						
Flow rate	mL/min	--	8.22	9.14	9.88	10.44
Combustible Gasses (as CH4)	ppm	540	440	920	640	620
O2	%	19.6	20.4	19.6	19.8	18.2
CO	ppm	12	0	24	18	22
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	28.25	13.88	15.38	12.00
11/24/2010						
Flow rate	mL/min	--	--	--	--	--
Combustible Gasses (as CH4)	% LEL	1	1	2	1	0
O2	%	20.2	19.8	18.8	20	19.2
CO	ppm	16	22	50	22	30
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	--	--	--	--
11/29/2010						
Flow rate	mL/min	--	10.35	10.13	10.58	10.3
Combustible Gasses (as CH4)	% LEL	--	1	1	1	1
O2	%	--	20.7	20	20.2	18.2
CO	ppm	--	0	25	17	25
CO2	ppm	--	0	0	0	0
ΔP	in H2O	--	23.5	9.5	22.0	10.5
12/3/2010						
Flow rate	mL/min	--	10.74	7.88	8.93	10.74
Combustible Gasses (as CH4)	ppm	--	430	830	630	450
O2	%	--	19.6	19.6	19.2	18.5
CO	ppm	--	0	25	6	0
CO2	ppm	--	0	0	0	0
ΔP	in H2O	--	27.0	7.5	26.0	15.0

TABLE 8

Portable Meter Periodic Offgas Monitoring Results
Diamond Head Superfund Site

Parameter	Units	BIOCELL-P1-1	BIOCELL-P1-2	BIOCELL-P1-3	BIOCELL-P1-4	BIOCELL-P1-5
12/6/2010						
Flow rate	mL/min	--	10.74	9.20	10.04	10.55
Combustible Gasses (as CH4)	ppm	450	450	740	560	680
O2	%	20.2	20.4	19.6	20.0	17.6
CO	ppm	10	2	30	17	24
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	23.0	6.5	24.0	11.5
12/10/2010						
Flow rate	mL/min	--	10.26	9.23	10.19	10.91
Combustible Gasses (as CH4)	ppm	420	200	410	480	620
O2	%	20.9	20.6	20.4	20	17.7
CO	ppm	4	0	15	16	20
CO2	ppm	0	100	0	0	0
ΔP	in H2O	--	20.0	7.0	25.0	11.0
12/14/2010						
Flow rate	mL/min	--	0	2.4	3.76	6.39
Combustible Gasses (as CH4)	ppm	430	440	690	610	700
O2	%	19.9	18.3	18.2	18.4	16
CO	ppm	8	36	66	44	39
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	10.5	20	24.0	7.5
12/17/2010						
Flow rate	mL/min	--	6.99	2.99	0	8.42
Combustible Gasses (as CH4)	ppm	390	240	1000	610	620
O2	%	19.4	20.1	15.1	18.5	17.2
CO	ppm	4	20	164	89	27.1
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	--	--	--	--
12/29/2010						
Flow rate	mL/min	--	9.76	8.97	9.73	9.27
Combustible Gasses (as CH4)	ppm	390	440	520	620	550
O2	%	20.1	19.4	19.6	18.4	16.9
CO	ppm	0	18	25	36	25
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	12	11.5	42.0	10
1/4/2011						
Flow rate	mL/min	--	9.44	9.01	9.30	9.48
Combustible Gasses (as CH4)	ppm	280	280	470	450	430
O2	%	20.8	20.2	20.0	19.0	17.2
CO	ppm	0	4	22	28	27
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	3	5	31.5	10.5
1/7/2011						
Flow rate	mL/min	--	9.72	9.38	10.32	9.71
Combustible Gasses (as CH4)	ppm	220	310	350	310	400
O2	%	20.8	20.2	20.2	19.3	17.2
CO	ppm	0	0	5	10	10
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	2.5	4.5	29	11

TABLE 8

Portable Meter Periodic Offgas Monitoring Results
Diamond Head Superfund Site

Parameter	Units	BIOCELL-P1-1	BIOCELL-P1-2	BIOCELL-P1-3	BIOCELL-P1-4	BIOCELL-P1-5
1/10/2011						
Flow rate	mL/min	--	8.07	0	1.46	9.83
Combustible Gasses (as CH4)	ppm	190	250	540	370	450
O2	%	20.6	20.0	18.4	18.3	17.1
CO	ppm	0	3	35	29	11
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	14.5	8.5	1.0	12.5
1/14/2011						
Flow rate	mL/min	--	8.92	4.10	8.01	7.68
Combustible Gasses (as CH4)	ppm	330	320	500	460	420
O2	%	20.9	20.3	20.1	19.1	17.3
CO	ppm	0	0	10	16	7
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	10	14.5	8.25	7.5
1/17/2011						
Flow rate	mL/min	--	7.12	9.78	9.11	9.07
Combustible Gasses (as CH4)	ppm	210	130	460	410	430
O2	%	20.8	20.8	20.0	19.1	16.7
CO	ppm	0	0	15	17	16
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	8	8.5	6.75	8
1/21/2011						
Flow rate	mL/min	--	10.48	10.02	9.05	9.16
Combustible Gasses (as CH4)	ppm	210	350	440	430	440
O2	%	20.8	20.1	19.9	19.1	17.0
CO	ppm	0	0	16	17	15
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	5.5	14	7.0	8
1/24/2011						
Flow rate	mL/min	--	10.96	8.02	9.94	9.78
Combustible Gasses (as CH4)	ppm	210	360	380	390	420
O2	%	20.8	20.2	19.8	19.0	16.8
CO	ppm	0	0	0	15	11
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	4	12.5	6.0	8
1/28/2011						
Flow rate	mL/min	--	9.57	9.96	9.69	9.43
Combustible Gasses (as CH4)	ppm	220	330	450	390	390
O2	%	20.8	20.0	19.9	18.9	16.9
CO	ppm	0	0	11	17	11
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	3	13	6.5	9
1/31/2011						
Flow rate	mL/min	--	10.00	8.23	9.77	9.43
Combustible Gasses (as CH4)	ppm	130	260	410	350	290
O2	%	20.9	20.2	19.8	19.1	17.4
CO	ppm	0	0	17	17	7
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	2	12.5	6	9.5

TABLE 8

Portable Meter Periodic Offgas Monitoring Results
Diamond Head Superfund Site

Parameter	Units	BIOCELL-P1-1	BIOCELL-P1-2	BIOCELL-P1-3	BIOCELL-P1-4	BIOCELL-P1-5
2/4/2011						
Flow rate	mL/min	--	9.69	9.02	10.32	9.52
Combustible Gasses (as CH4)	ppm	130	240	360	280	290
O2	%	20.9	20.6	20.4	19.3	17.4
CO	ppm	0	0	9	17	19
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	1	11	7	9
2/7/2011						
Flow rate	mL/min	--	10.46	11.11	8.12	9.85
Combustible Gasses (as CH4)	ppm	95	220	330	290	270
O2	%	20.9	20.3	20.2	19.2	17.0
CO	ppm	0	0	11	17	11
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	1.5	10	7	9
2/11/2011						
Flow rate	mL/min	--	11.02	10.84	11.05	9.79
Combustible Gasses (as CH4)	ppm	100	190	350	310	320
O2	%	20.8	20.2	20.0	19.0	17.4
CO	ppm	0	0	0	11	0
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	1	9	8	10
2/14/2011						
Flow rate	mL/min	--	13.74	12.19	10.79	10.2
Combustible Gasses (as CH4)	ppm	130	260	380	330	310
O2	%	20.2	19.3	19.2	18.6	17.2
CO	ppm	0	0	6	17	7
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	1	12.5	8	11
2/18/2011						
Flow rate	mL/min	--	11.18	12.42	11.00	10.49
Combustible Gasses (as CH4)	ppm	130	260	350	290	280
O2	%	20.4	19.7	19.7	19.1	17.2
CO	ppm	0	0	5	15	7
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	1	9	5	12
2/21/2011						
Flow rate	mL/min	--	11.51	11.03	13.41	10.56
Combustible Gasses (as CH4)	ppm	80	200	220	290	270
O2	%	20.5	19.9	20.0	19.0	17.2
CO	ppm	0	0	0	17	7
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	1	8	7	11
2/25/2011						
Flow rate	mL/min	--	10.91	10.84	10.67	9.91
Combustible Gasses (as CH4)	ppm	170	230	290	360	320
O2	%	20.4	20.2	20.1	19.0	17.5
CO	ppm	0	0	0	15	2
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	0.67	6	7.75	11

TABLE 8

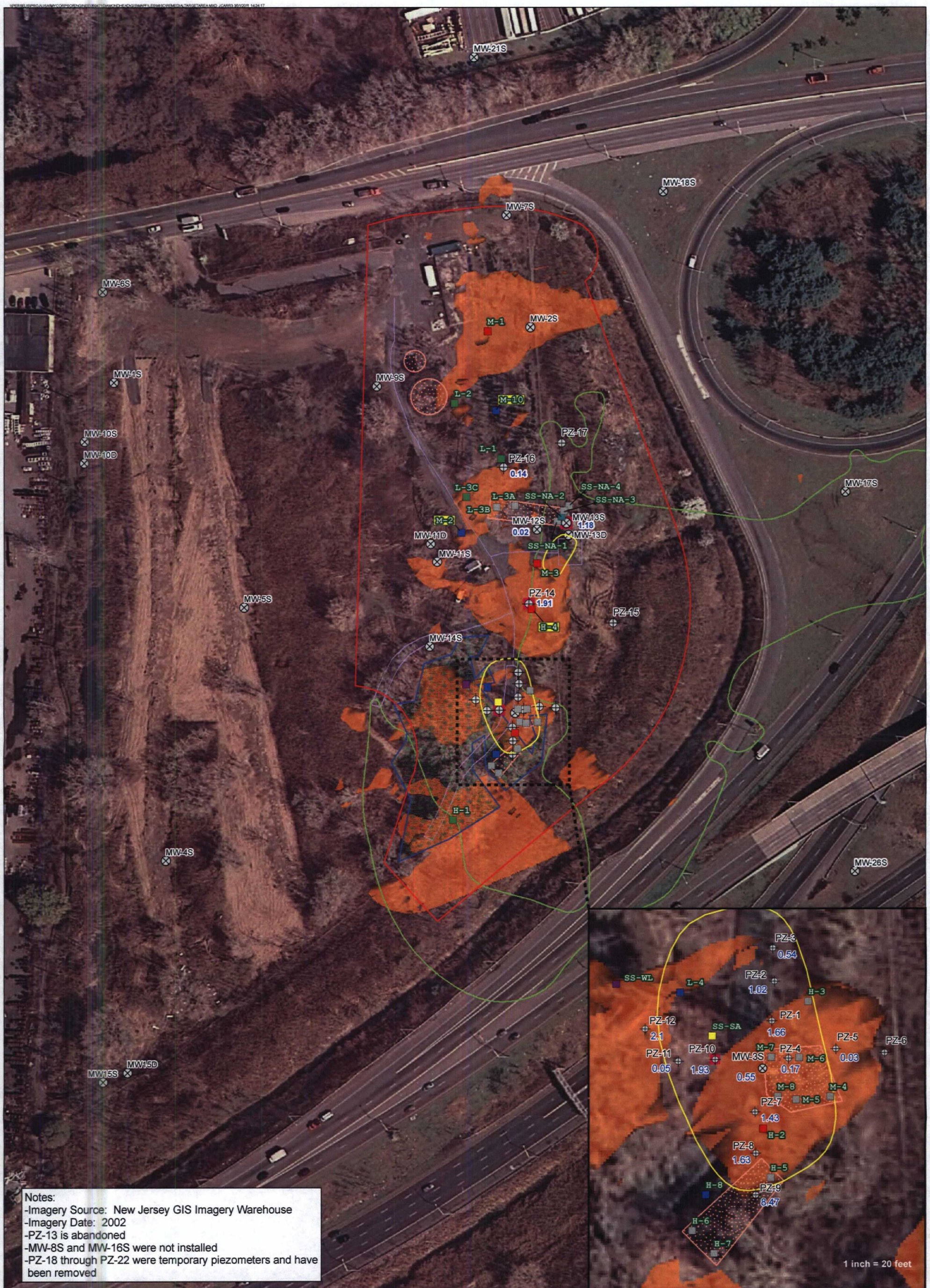
Portable Meter Periodic Offgas Monitoring Results
Diamond Head Superfund Site

Parameter	Units	BIOCELL-P1-1	BIOCELL-P1-2	BIOCELL-P1-3	BIOCELL-P1-4	BIOCELL-P1-5
2/28/2011						
Flow rate	mL/min	--	10.02	10.87	11.04	10.69
Combustible Gasses (as CH4)	ppm	170	290	410	370	350
O2	%	20.2	19.8	19.6	18.8	17.3
CO	ppm	0	0	3	16	3
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	0.33	6	6.5	11
3/4/2011						
Flow rate	mL/min	--	14.28	11.58	11.68	12.26
Combustible Gasses (as CH4)	ppm	180	300	310	340	300
O2	%	20.5	19.9	19.0	18.9	17.6
CO	ppm	0	0	0	15	1
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	0.67	10	7.5	12
3/7/2011						
Flow rate	mL/min	--	12.74	11.4	11.39	11.51
Combustible Gasses (as CH4)	ppm	120	260	380	330	310
O2	%	20.2	19.6	19.6	18.8	17.4
CO	ppm	0	0	6	16	3
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	0.50	10.75	6.0	12.5
3/11/2011						
Flow rate	mL/min	--	11.35	10.66	11.30	11.95
Combustible Gasses (as CH4)	ppm	170	270	370	320	280
O2	%	20.4	19.9	19.8	19.1	17.6
CO	ppm	0	0	3	15	0
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	0.67	8.5	7.0	12.5
3/14/2011						
Flow rate	mL/min	--	10.63	10.58	11.22	12.03
Combustible Gasses (as CH4)	ppm	100	190	330	320	270
O2	%	20.4	19.9	19.8	19.0	17.5
CO	ppm	0	0	3	17	2
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	0.50	6.5	8.0	14
3/18/2011						
Flow rate	mL/min	--	11.73	9.21	12.08	12.78
Combustible Gasses (as CH4)	ppm	200	310	410	370	280
O2	%	20	19.3	19.3	18.7	17.7
CO	ppm	0	0	2	15	0
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	0.33	7	7.5	13.5
3/21/2011						
Flow rate	mL/min	--	12.31	11.83	11.69	12.19
Combustible Gasses (as CH4)	ppm	200	300	410	360	260
O2	%	19.8	19.2	19.1	18.6	17.6
CO	ppm	0	0	3	16	0
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	0.50	8	7.0	14.5
3/24/2011						
Flow rate	mL/min	--	10.76	11.14	13.20	11.68
Combustible Gasses (as CH4)	ppm	210	300	400	310	270
O2	%	19.7	19.2	19.1	18.8	17.6
CO	ppm	0	0	4	8	0
CO2	ppm	0	0	0	0	0
ΔP	in H2O	--	0.50	7	8.0	13

Notes:

Typical ambient readings: CH4 = 0 ppm, O2 = 20.9%, CO = 0 ppm, CO2 = 0 ppm

CH4 monitored on the RKL Eagle field meter includes response to other flammable gasses such as BTEX.











Notes:


- Imagery Source: New Jersey GIS Imagery Warehouse
- Imagery Date: 2002
- PZ-13 is abandoned
- MW-8S and MW-16S were not installed
- PZ-18 through PZ-22 were temporary piezometers and have been removed


Legend

Test Pit


-  High Contamination Trenches (Collected Soil for Bench Scale Testing)
-  Medium Contamination Trenches (Collected Soil for Bench Scale Testing)
-  Low Contamination Trenches (Collected Soil for Bench Scale Testing)
-  Trenches That Were Not Sampled for Bench Scale Testing
-  Stabilization/Solidification Test Waste Lagoon Area
-  Stabilization/Solidification Test Waste Northern Area
-  Stabilization/Solidification Test Southern Area
-  Approximate Concrete Underlain Area (Surficial and/or at Depth)


Phase 1 Monitoring Wells

 LNAPL Sampling Locations







 Monitoring Wells

Phase 1 Piezometers

 LNAPL Sampling Locations

 Piezometers

PZ-4 — Location ID
0.17 — NAPL Thickness 8/30/10

 Temporary Gravel Road
 Extent of Historical Source Area (1976 Aerial Photo)
 Delineated Wetlands
 Approximate RTA
 Measureable LNAPL in Wells
 Remedial Target Area

Denotes a test pit from which additional samples were collected based on filed observations, such as the presence of a white clay-like material, potential petroleum waste sludge material, and/or reddish-brown and olive-yellow clay-like material.

A horizontal scale bar with tick marks at 0, 75, 150, and 300 feet. The bar is divided into three segments: a black segment from 0 to 75 feet, a white segment from 75 to 150 feet, and a black segment from 150 to 300 feet. The word "Feet" is written at the right end of the bar.

Figure 1
Sampling Locations
PDI Bench Scale Test
Diamond Head Oil
Kearny, NJ 07032

Attachment A

TABLE A-1

Phase I Biocell Test Setup Summary
Diamond Head Superfund Site

Volumetric bulking ratio (Vs/ Vt)
Mass-based bulking ratio (Ms/Mt)

	unbulked	bulked
Moisture Content	0.353	0.351 as-received
Water holding capacity	0.467	-- Measured
Moisture Content, optimal for biodeg	0.350	-- Assumed to be 75% of the WHC
Column media volume	0.785	0.785 ft3
85% Proctor compaction bulk density	73.7	68.6 lb/ft3, dry

0.833 as-received
0.971 as-received

Michael Niemet:
A 5:1 mix of soil to wood chips
appeared to slightly fluff the soil.

Michael Niemet:
Based on masses for scoops
above.

Michael Niemet:
Vendor recommends 1
gallon per 10 cy

Michael Niemet:
TPH = 16,600 mg/kg.
Vendor recommends 1:1
addition to TPH.

Michael Niemet:
Titration determined 2 lbs
needed per 45.2 pounds
dry soil to achieve pH = 7.3

Michael Niemet:
Enough to dissolve N & P but not
overwet soil.

Michael Niemet:
Target = 100 mg P/kg = 458 mg
Na2HPO4/kg

Michael Niemet:
Target = 250 mg N/kg = 955 mg
NH4Cl/kg

Amendments: Note - Add 1/8 of the portions below to each 6" lift to promote even distribution

Sample	Amendments	Media added [lb, dry]	Media Added [lb, as-rec]	Media Added per 6" lift [lb, as-rec]	Soil Added [lb, as-rec]	Wood Chips [lb, as-rec]	Water added with media [lb]	Al2(SO4)3 [lb]	Oil Buster [lb]	Micro-Blaze 3% soln' [mL]	NH4Cl [g]	Na2HPO4 [g]	Water added with N & P [lb]	Water added with N & P [L]	Final moisture content
BIOCELL-P1-1	None	57.9	89.5	11.2	89.5	0	31.6	0	0	0	0	0	0	0	0.353
BIOCELL-P1-2	Air, water	57.9	89.5	11.2	89.5	0	31.6	0	0	0	0	0	0	0	0.353
BIOCELL-P1-3	Air, water, bulking agent, nutrients	53.9	83.0	10.4	80.6	2.43	29.1	0	0	0	23.3	11.2	2.2	1.00	0.368
BIOCELL-P1-4	Air, water, bulking agent, nutrients, pH adjustment	53.9	83.0	10.4	80.6	2.43	29.1	2.31	0	0	23.3	11.2	2.2	1.00	0.358
BIOCELL-P1-5	Air, water, bulking agent, nutrients, pH adjustment, organic substrate	53.9	83.0	10.4	80.6	2.43	29.1	2.31	0.866	11.01	23.3	11.2	2.2	1.00	0.355
divide by 8: grams								0.288 130.8	0.108 49.1	1.376	2.917	1.399	0.276 125.0	0.125	

TABLE A-2

Phase I Biocell Test Setup - Proctor Compaction Screening for As-Received Soil
Diamond Head Superfund Site

Sample ID	Tare	Wet + Tare	Dry + Tare	Molding Water Content	Vol	Vol	Moist Soil plus mold	Mass of mold	Moist Mass of Soil	Moist Density	Dry density	Dry unit weight	Dry unit weight
	[g]	[g]	[g]	[%]	[ft ³]	[cm ³]	[g]	[g]	[g]	[g/cm ³]	[g/cm ³]	[lb/ft ³]	[kN/m ³]
1	0.9914	14.404	11.62	0.26	0.0333	943	5860.1	4209.9	1650.2	1.750	1.388847	86.70293	13.6198651
6	0.9995	27.861	21.48	0.30	0.0333	943	5872.7	4209.9	1662.8	1.763	1.356391	84.67679	13.30158617
2	0.9967	24.404	18.03	0.37	0.0333	943	5850.1	4209.9	1640.2	1.739	1.265705	79.01545	12.41226532
5	0.9945	35.15	25.3	0.41	0.0333	943	5834.4	4209.9	1624.5	1.723	1.225891	76.52994	12.02182486
9	0.97	16.9	15.08	0.13	0.0333	943	5652.7	4209.9	1442.8	1.530	1.355207	84.60287	13.28997427
10	0.94	18.02	15.46	0.18	0.0333	943	5710.1	4209.9	1500.2	1.591	1.352434	84.42978	13.26278348

sorted results	
0.13	84.60287
0.18	84.42978
0.26	86.70293 max
0.3	84.67679
0.37	79.01545
0.41	76.52994

0.114249843

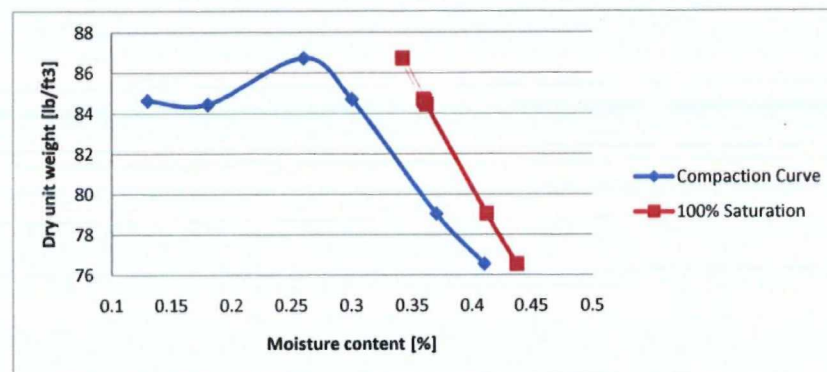


TABLE A-3

Phase I Biocell Test Setup - Proctor Compaction Screening for Bulk Soil
Diamond Head Superfund Site

Sample ID	Tare [g]	Wet + Tare [g]	Dry + Tare [g]	Actual Molding Water Content [%]	Vol [ft ³]	Vol [cm ³]	Moist Soil plus mold [g]	Mass of mold [g]	Moist Mass of Soil [g]	Moist Density [g/cm ³]	Dry density [g/cm ³]	Dry unit weight [lb/ft ³]	Dry unit weight [kN/m ³]
5	1.33	18.79	17.37	0.09	0.0333	943	5504.1	4209.9	1294.2	1.37242842	1.261	78.710	12.364
3	1.29	10.70	9.50	0.15	0.0333	943	5561.8	4209.9	1351.9	1.433616119	1.251	78.085	12.266
4	1.28	20.99	17.01	0.25	0.0333	943	5736.4	4209.9	1526.5	1.618769883	1.292	80.650	12.669
7	1.01	21.56	14.35	0.54	0.0333	943	5771.7	4209.9	1561.8	1.656203606	1.075	67.118	10.543
6	1.33	40.05	25.26	0.62	0.0333	943	5697.9	4209.9	1488	1.577942736	0.975	60.880	9.564

0.350851582

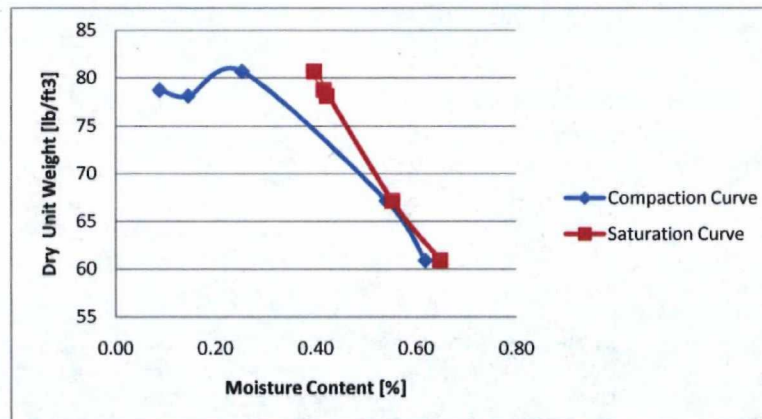


TABLE A-4

Phase I Biocell Test Setup - Aluminum Sulfate Soil Titration

Diamond Head Superfund Site

CH2MHILL

Titration Curve

Sample Information		Test Information	
Client		Analyst	MAS
Source	Diamond Head Superfund Site	Test Date/Time	11/8/2010 10:30
Sample Date/Time		Sample Volume*	150 mL
Project Number		Sample Mass (g), air dry	51.0
Client Sample ID		Sample Mass (g), dry	45.2
Lab Sample ID	Phase 1 Soil		

*Added 100 mL DI water to 51.0 g soil

Reagent Characteristics			
Type	Acid	Base	Other
Chemical			Al ₂ (SO ₄) ₃
Reagent Strength			

Measurements							
pH	0.00 (g)	0.00 (mg)		pH	0.00 (mL)	0.00 (uL)	
11.48	0.00	0.0					
9.82	0.50	500.0					
8.80	1.00	1000.0					
8.08	1.50	1500.0					
7.30	2.00	2000.0					
7.15	2.25	2250.0					
6.95	2.50	2500.0					
6.66	3.00	3000.0					

TABLE A-5

Estimated Hydrocarbon Degradation Rate from O₂ Consumption - Phase I Biocell Column Treatability Test

Diamond Head Superfund Site

Given:

[Airflow] =	0.00035 scfm or	10 ml/min	
[Effluent O ₂] =	17.5 % by vol =	175,000 ppmv	
[Background O ₂] =	20.9 % by vol =	209,000 ppmv	
[Temperature] =	70 °F =	21.1 °C =	294.3 °K
[Absolute Pressure] =	235 ft amsl =	753 mm Hg	
[MW O ₂] =	32 g/mole		
Specific Gravity of HC =	0.87		

Step 1: Determine the volume in one mole of gas

Standard T and P = 0 °C and 759 mm Hg = 22.4 L/mole gas

$$\left. \begin{array}{l} P_1 V_1 = nRT_1 \\ P_2 V_2 = nRT_2 \end{array} \right\} \quad \begin{array}{l} V_2 = V_1 [P_1 T_2 / P_2 T_1] \\ V_2 = 24.3 \text{ L/mol (at site conditions)} \end{array}$$

Step 2: Determine the rate of oxygen consumption

$$[\text{O}_2 \text{ Consumed}] = \{ [\text{Background O}_2] - [\text{Effluent O}_2] \} / 100 / [\text{Molar Volume}] * [\text{MW O}_2] * [\text{Airflow}] * (1440 \text{ min/day}) * (28.3 \text{ L/ft}^3) / (1000 \text{ g/kg}) * (2.2 \text{ lb/kg})$$

$$[\text{O}_2 \text{ Consumed}] = 0.001 \text{ lbs O}_2/\text{day}$$

Step 3: Estimate hydrocarbon degradation rateAssume stoichiometric ratio of 3.45 lbsO₂ consumed to degrade 1lb of hydrocarbon (C₃₀H₆₂-MW=422 g/mol)

$$[\text{HC Degradation}] = 0.0004 \text{ lbs HC/day} = 186 \text{ mg HC/day}$$

Assumed aerated zone:

Diameter =	0.5 ft	
Depth =	4.0 ft	
Soil Bulk Density =	69 lbs/ft ³ (dry)	
Volume/Mass =	0.8 ft ³ or	25 kg soil

$$[\text{HC Degradation}] = 7.6 \text{ mg-HC/kg-soil/day}$$

Initial HC Concentration =	9,000 mg/kg
Test Duration =	2 months
Estimated Final HC Concentration =	8,538 mg/kg
Initial HC Concentration =	9,000 mg/kg
Test Duration =	12 months
Estimated Final HC Concentration =	6,229 mg/kg

TABLE A-6

Geophysical Testing Results

Diamond Head Superfund Site

Parameter	Units	Bulked Soil	Amended soil (bulk + organics + nutrients + pH control)
SUMMARY OF CONSOLIDATION TEST DATA (ASTM D 2435)			
C _c		0.42	0.42
C _r		0.02	0.01
C _v	in ² /sec	0.010	0.004
P _c	tsf	3.7	2.3
P ₀		Remolded sample	Remolded sample
OCR		Remolded sample	Remolded sample
e ₀		1.42	1.47
w ₀	%	32.0	33
G _s		2.62	2.62
Y _d	pcf	67.4	66.2
w _L	%	62	72
w _P	%	40	45
I _p	%	22	27
COMPACTION TEST RESULTS (ASTM D 698)			
Maximum Dry Density	pcf	85	80
Optimum Moisture Content	%	23	31
ATTERBERG LIMITS (ASTM D 4318-05)			
w ₀	%	51	56
w _L	%	62	72
w _P	%	40	45
I _p	%	22	27
SIEVE ANALYSIS SUMMARY (ASTM D 433-63)			
% Gravel	%	28	28
% Sand	%	42	40
% Silt	%	26	26
% Clay	%	5	6
D ₆₀	mm	1.1265	1.3383
D ₃₀	mm	0.0724	0.0639
D ₁₀	mm	0.0118	0.0087
C _u (coefficient of uniformity)		95	154
C _c (coefficient of curvature)		0.39	0.35
USCS -		Silty Sand with Gravel (SM)	Silty Sand with Gravel (SM)